DOCUMENT RESUME

ED 053 946 24 SE 012 152

AUTHOR	Pfeiffer, Carl H.
TITLE	Homeostatic Systems--Mechanisms for Survival. Science IV.
INSTITUTION	Monona Grove High School, Monona, Wis.; Wisconsin State Dept. of Education, Madison.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C. Bureau of Research.
BUREAU NO	BR-5-0646
PUB DATE	68
NOTE	362p.; Due to copyright restrictions, some pages are not included
EDRS PRICE	EDRS Price MF-$0.65 HC-$13.16
DESCRIPTORS	Biology, Chemistry, *Fused Curriculum, *Instructional Materials, *Integrated Curriculum, *Interdisciplinary Approach, Physics, *Science Activities, Scientific Principles, Secondary School Science

ABSTRACT

The two student notebooks in this set provide the basic outline and assignments for the fourth and last year of a senior high school unified science program which builds on the technical third year course, Science IIIA (see SE 012 149). An introductory section considers the problems of survival inherent in living systems, matter-energy interactions relating to living systems, life and the laws of thermodynamics, and homeostasis. The first unit, Matter-Energy Relationships of the Electron, focuses on interactions involving circular movement, translational movement, and movements between electric and magnetic fields. The second unit, Mechanisms for Matter-Energy Interactions in Living Organisms, considers those mechanisms associated with the capture, storage and utilization of energy and matter, transport, regulation and exchange of matter, and other functions in living organisms. The materials for each of the sub-units include: a list of required and recommended readings from various other books; questions for consideration in introducing a lesson; a brief background reading; a basic outline of the lectures with space provided within the outline for notes; laboratory activities and investigations; laboratory problem reports and other kinds of assignments (discussion questions, fill-ins, problems); and summary statements and review questions. Numerous diagrams and illustrations are included. (PR)

ED0 53946

PA-24
BR-5-0646

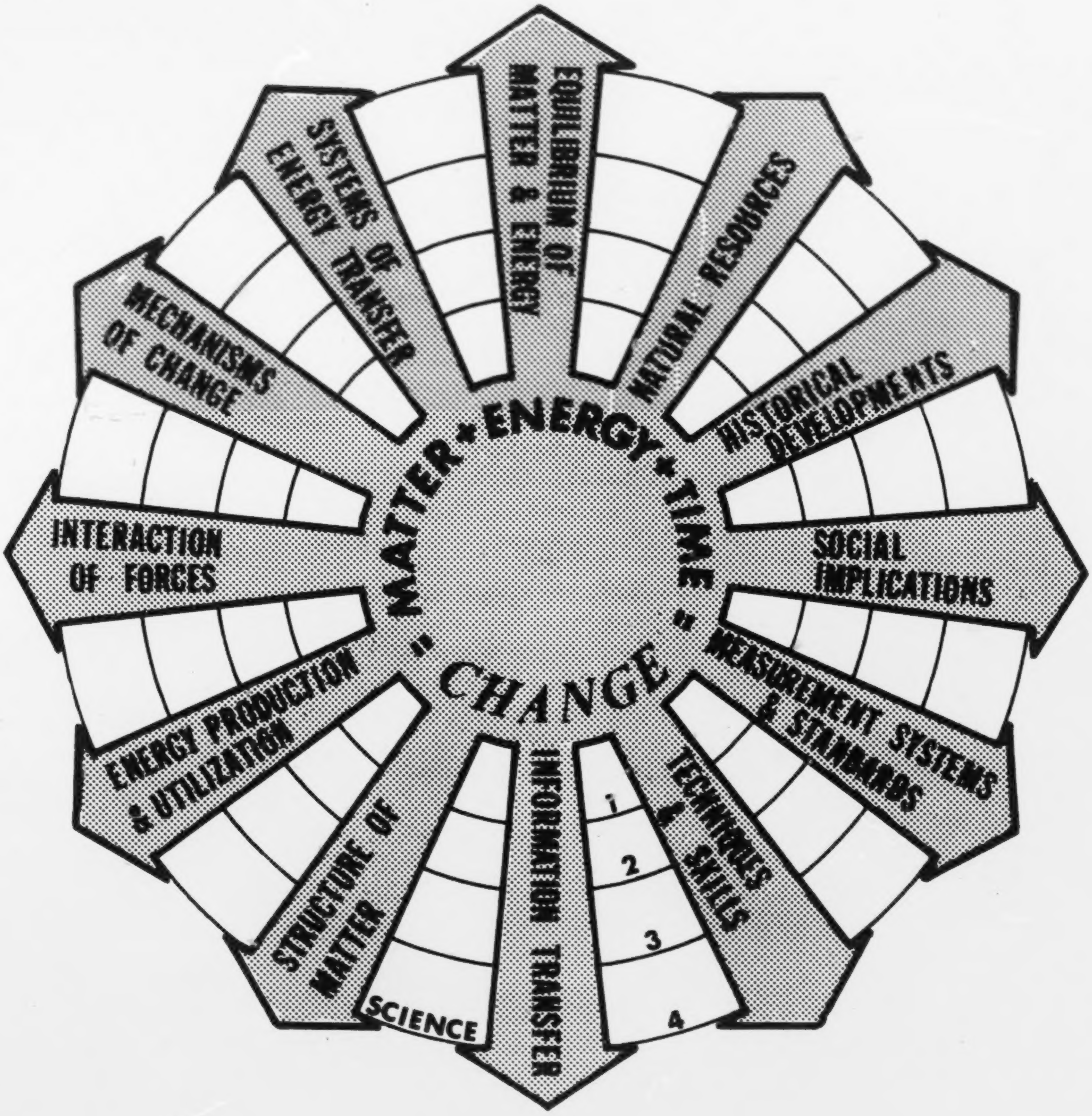
Carl H. Pfeiffer
Wisconsin State Department of Education

SE

SE012 152

UNIFYING THEMES

MONONA GROVE UNIFIED SCIENCE PROGRAM


EQUILIBRIUM OF MATTER & ENERGY
NATURAL RESOURCES
HISTORICAL DEVELOPMENTS
SOCIAL IMPLICATIONS
MEASUREMENT SYSTEMS & STANDARDS
TECHNIQUES & SKILLS
INFORMATION TRANSFER
STRUCTURE OF MATTER
ENERGY PRODUCTION & UTILIZATION
INTERACTION OF FORCES
MECHANISMS OF CHANGE
SYSTEMS OF ENERGY TRANSFER
" MATTER + ENERGY + TIME "
CHANGE
1
2
3
4
SCIENCE

INTRODUCTION

I. Class Procedures and Regulations

A. Grouping

1. Large Groups (50-55 Students)	Rooms -- 67, 61
2. Laboratory Groups (24 Students)	Rooms -- 61, 73, and 69
3. Small Groups (15-18 Students)	Rooms -- 61, 73, 69, 67, 65 and other available rooms

When groups move from one room to another during a class session, the movement is expected to be accomplished quickly and quietly.

B. Personal Responsibility in the Classroom

1. When the bell signaling the beginning of a class session sounds, students are expected to come to order without further direction. Students not in their assigned seats at this time are considered to be tardy.
2. Students reporting to class late must present an "admit to class" pass.
3. The class will be dismissed by the teacher, not the bell, at the end of the class session.
4. Students detained by the teacher after the bell should obtain an admit to class pass before leaving the room.
5. Before leaving the classroom!
   a. Check your desk including the shelf and floor area to be sure that they are cleared of debris and in order.
   b. Place your chair under the desk.
6. The science department office located between rooms 61 and 65, is not to be used as a passage way by students.

C. Note Taking

1. The student notebook provides a basic outline of the course content.
2. Regular, careful, note taking in large group sessions is required in order to make the student notebook a useful reference for study.
3. An audio tape on effective note taking is available in the Resource Center.
4. Notebooks will be collected periodically to evaluate the quality of note taking.

D. Assignments

1. Assignment schedules will be given periodically. These schedules should be used to help budget time for homework and study for quiz sessions and hour examinations.

2. Types of homework assignments

   a. Reference reading:

      (1) Reading assignments will be made from selected references located in the Resource Center.

      (2) Generally the required reading assignments will also be available on audio tape.

      (3) "Check tests", one or two questions, will frequently follow a reading assignment.

   b. Problems, exercises and discussion questions:

      Duplicate copies of all problem assignments, exercises and discussion questions appear in the notebook. Carbon copies are handed in for evaluation.

   c. Laboratory reports - to be completed on special laboratory report forms.

3. Regulations pertaining to homework assignments

   a. On days when assignment is due at the beginning of the class session homework will be collected when the bell rings.

      (1) Problems, exercises or discussion questions missing after the collection of homework will be recorded as an F and be reflected in the Individual Performance Grade.

      (2) When excused absence is a factor the F may be converted to full credit provided that the assignment is completed within a specified period.

      (3) Laboratory reports missing at the time of collection will be graded F in Knowledge and Skills and affect the Individual Performance Grade.

      (4) If excused absence is not a factor, late laboratory reports may be submitted for a maximum of ½ credit in Knowledge and Skills.

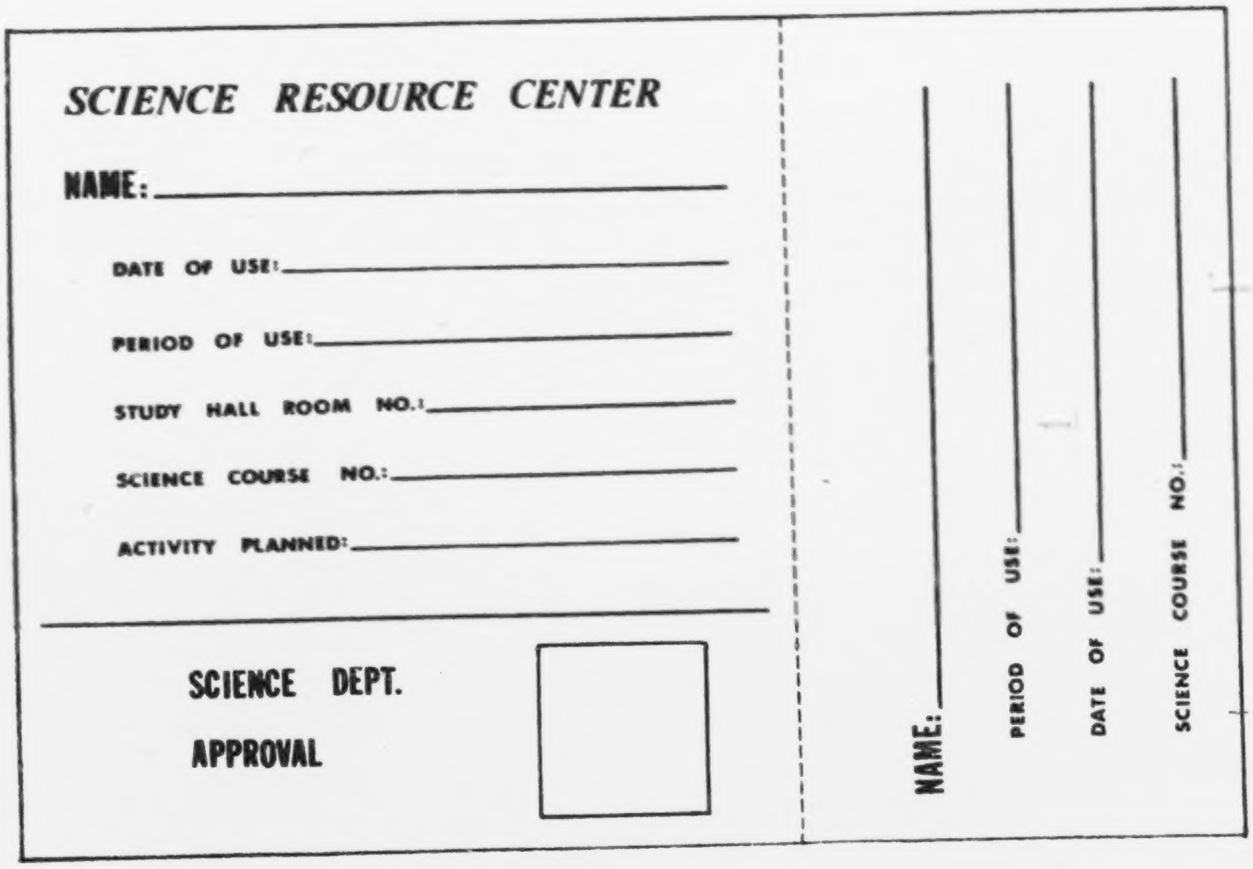
   b. Students absent from class are responsible for arrangements to complete assignments missed.

      (1) Assignments not handed in the day after returning to class will be graded as F, except in cases where requests for an extension of time have been approved.

      (2) Arrangements for making up a scheduled quiz or an hour examination must be completed the day the student returns to class. Any quiz or hour exam not made up will be averaged as F in the Knowledge and Skills Grade.

II. Science Resource Center

A. Use of the Resource Center Facilities



SCIENCE RESOURCE CENTER

NAME: ____

DATE OF USE: ____

PERIOD OF USE: ____

STUDY HALL ROOM NO.: ____

SCIENCE COURSE NO.: ____

ACTIVITY PLANNED: ____

SCIENCE DEPT. APPROVAL ☐

NAME: ____

PERIOD OF USE: ____

DATE OF USE: ____

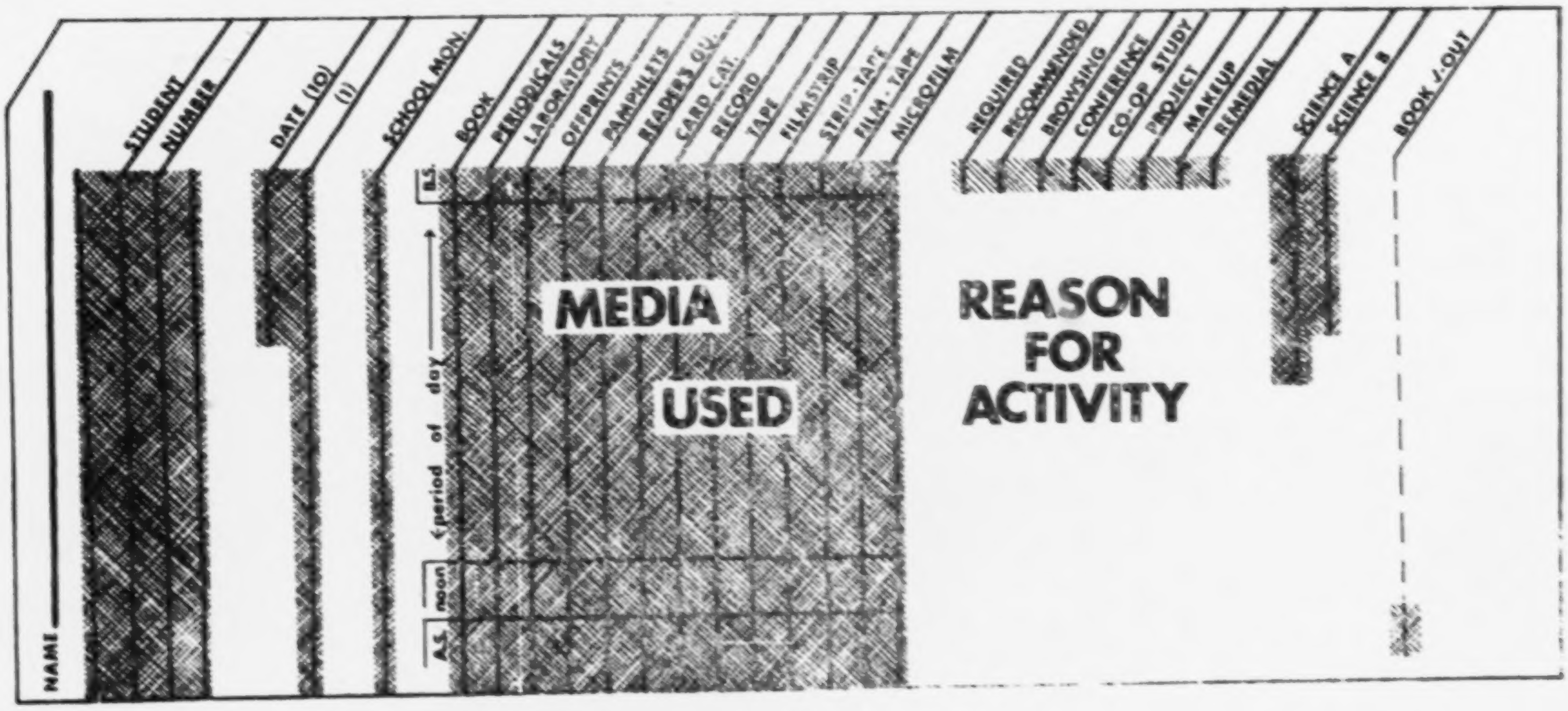
SCIENCE COURSE NO.: ____

1. The Resource Center may be used during any regularly scheduled study hall period by the "pass" system.
2. The Resource Center will be open from 12:15 to 12:45 every Tuesday, Wednesday, and Thursday noon.
3. Students wishing to use the Resource Center Facilities before or after school may do so by appointment.
4. Students must demonstrate the degree of self discipline necessary for effective independent or cooperative study in the Resource Center.

B. Circulation of Resource Center Reference Materials

1. No materials will be checked out during the school day.
2. Books, magazines, offprints, and special materials may be checked out on an "overnight" basis only. Check out period is from 3:45 to 4:00 p.m. daily.
3. All materials must be returned by 8:00 a.m. the next day.
4. Failure to comply with any of the above procedures will be reflected in the Citizenship Grade.

C. Use of the Porta-Punch Card


NAME
STUDENT
NUMBER
DATE (10)
(1)
SCHOOL MON.
BOOK
PERIODICALS
LABORATORY
OFFPRINTS
PAMPHLETS
READERS GU.
CARD CAT.
RECORD
TAPE
FILMSTRIP
STRIP-TAPE
FILM-TAPE
MICROFILM
B.S.
period of day
noon
A.S.
MEDIA
USED
REQUIRED
RECOMMENDED
BROWSING
CONFERENCE
CO-OP STUDY
PROJECT
MAKEUP
REMEDIAL
REASON
FOR
ACTIVITY
SCIENCE A
SCIENCE B
BOOK √-OUT

1. Print your name on the card.
2. Punch out the correct information on the shaded (red) area.

D. Guide to Student Use of the Science Resource Center

1. The Science Resource Center is designed and equipped to provide an opportunity for students to do independent or cooperative study in the area of science.
2. Students who come to the Resource Center must have a specific purpose which requires the use of the facilities in the Center!
3. Students who use the Resource Center Facilities must record the nature of their activity in the Center by use of the Porta-Punch Card.
4. All cooperative study between two students must be done at the conference tables. Students sitting at the study carrels are expected to work individually without any conversation with other students.
5. All students are encouraged to take advantage of the opportunities that the Resource Center provides for individual help with any problems or difficulties experienced in their science course.
6. The use of the Resource Center Facilities requires self discipline on the part of the student in order to develop effective individual study skills. Students who are unable to exercise the self discipline required to maintain an atmosphere conducive to independent study will not be permitted to use the Resource Center Facilities until such time that they can demonstrate this ability.
7. Maintenance Responsibilities
   a. Turn volume off when headsets are not in use.
   b. Leave all reference books on the carrel shelf in good order. All cataloged books and periodicals are to be returned to the proper space in the drawers or shelves.
   c. Keep desk storage area free of debris and desk surfaces clean.

III. Grades and grading

A. Basis for the evaluation of Individual Performance and School Citizenship:

*See accompanying sheets or student handbook for points considered in grading these categories. Individual Performance and School Citizenship will be evaluated three times each quarter.

B. Basis for the evaluation of student progress in the area of Knowledge and Skills:

1. The grade point system

4.0 3.9 3.8	4.3 A+
3.7 3.6 3.5	4.0 A
3.4 3.3 3.2	3.7 A-
3.1 3.0	3.3 B+
2.9 2.8 2.7	3.0 B
2.6 2.5	2.7 B-
2.4 2.3 2.2	2.3 C+
2.1 2.0 1.9	2.0 C
1.8 1.7 1.6	1.7 C-
1.5 1.4	1.3 D+
1.3 1.2 1.1	1.0 D
1.0 .9	.7 D-
.8 .7 .6 .5	.3 F+
.4 .3 .1 .0	.0 F

2. Determination of grade point

Daily Work - ½ of Knowledge and Skills Grade

Quizzes a. short 5 minute unannounced test covering material presented in large group sessions or homework assignments

b. 15-30 minute announced test

Written laboratory problem and investigation reports

Hour Examinations - ½ of Knowledge and Skills Grade

Daily work and hour examinations not completed will be averaged as zero.

C. Final Total Growth Grade

1. Each of the four, quarterly, total growth grades plus the Final Evaluation are averaged equally to give the final Total Growth Grade in the course.

2. Final Evaluation

a. The final written examination in the course will count as one-half of the Final Evaluation.

b. A final appraisal of Individual Performance and School Citizenship will determine the remaining half of the Final Evaluation Grade.

FACTORS DEFINING INDIVIDUAL PERFORMANCE

Works up to ability

1. Does work which compares favorably with ability as measured by test scores.
2. Does daily work which compares favorably with best work done in a grading period.
3. Tries to make the best use of his particular talents and opportunities.
4. Carefully completes each day's assignment.
5. Reworks and corrects errors in assignments after class checking.
6. Goes beyond regular assignments to learn more about the subject.
7. Spends time reviewing.
8. Shows improvement rather than staying at one point.

Has a positive attitude

1. Has a sincere desire and interest in learning.
2. Is willing to try - is willing to be exposed to new information and ideas.
3. Has respect for the opinions of others.
4. Accepts correction well and constantly tries to improve.
5. Takes pride in his work.
6. Responds as well to group instruction as to individual instruction.
7. Does not argue over trivial points.
8. Does not show negative feelings in class - straightens things out alone with teacher.
9. Is willing to accept special jobs.

Shows self-direction

1. Demonstrates ability to carry on independent or cooperative study using Resource Center materials.
2. Works for understanding rather than a grade.
3. Is self-starting and self-sustaining.
4. Does his own work - has confidence in it.
5. Tries assignments himself before seeking help.
6. Knows when and how to seek help.
7. Initiates makeup assignments and does them promptly.
8. Is resourceful- uses imagination.
9. Settles down to work immediately.
10. Shows initiative.

Plans work wisely

1. Completes assignments and turns them in on time.
2. Is prepared for class - brings all necessary materials.
3. Makes good use of study time.
4. Follows directions.
5. Anticipates needs in work projects.
6. Organizes time so there is no last minute rush job.
7. Moves quickly and quietly when given an assignment.

FACTORS DEFINING SCHOOL CITIZENSHIP

Is courteous and considerate of others

1. Is courteous to other students, to teachers or any person with whom he comes in contact, for example the custodial staff.
2. Is quiet and attentive in class discussion.
3. Listens carefully to student questions, answers and comments as well as to those of the teacher.
4. Uses only constructive criticism - avoids ridicule.
5. Is tolerant of errors made by others.
6. Receives recognition before speaking.
7. Is ready to begin work when the bell rings.
8. Accepts the "spirit" as well as the letter of school regulations.
9. Shows halllway conduct which is orderly and in good taste.
10. Shows good assembly conduct.
11. Is quiet and attentive during P.A. announcements.
12. Is quiet in hallways when school is in session.
13. Carries out classroom activity in a quiet and businesslike manner.

Is responsible

1. Demonstrates self discipline necessary for effective use of Resource Center Facilities.
2. Keeps appointments.
3. Carries out assigned tasks.
4. Can be left unsupervised for a period of time.
5. Gets to class on time.
6. Meets obligations, fees, etc.
7. Returns borrowed items.
8. Has a good attendance record.
9. Keeps name off library list.
10. Presents excuse for absence.
11. Returns report card on time.

Contributes his share

1. Works to develop and uphold the good reputation of the school.
2. Participates in class discussion in a constructive manner - asks questions as well as volunteering information - shares ideas.
3. Participates in at least one school activity as a cooperative, contributing member.
4. Accepts jobs such as taking part in panels, putting up bulletin boards, helping direct class activities, getting information.
5. Brings examples, clippings, supplementary materials to class.
6. Contributes to success of class in a physical way - straightens chairs, pulls blinds, etc.

Is a good leader or follower

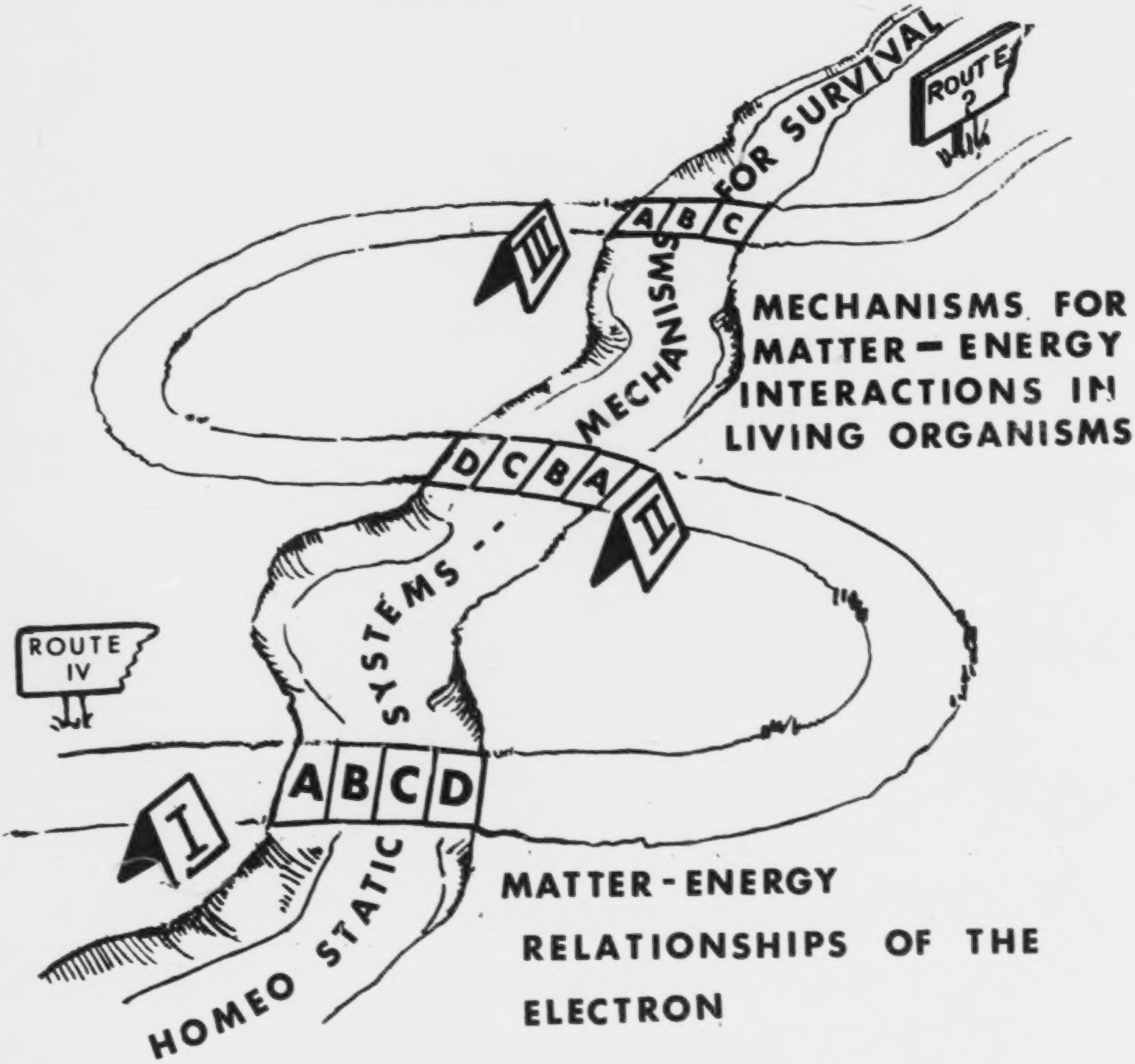
1. Cooperates willingly with the majority even though his point of view is with the minority.
2. Works constructively to change practices he is not in agreement with.
3. Works willingly with any group, not just his particular friends.
4. Helps class move along positively.
5. Leads in class discussion.
6. Responds to suggestions.

7. Gets others to participate.
8. Helps other students learn without simply giving them answers.
9. Is compatible with the group or class.
10. Avoids trying to be the center of attention.

Takes care of school and personal property

1. Handles and uses school equipment and materials with care.
2. Cooperates in keeping school building and grounds clean, free from litter and in excellent condition.
3. Is concerned about clean-up at the end of a class period.
4. Erases pencil marks and picks up paper when others have been careless.
5. Respects property of others.
6. Returns materials to correct places.
7. Avoids marking desks, books, etc.
8. Covers text books.
9. Disposes of gum, paper, etc., properly.
10. Keeps locker clean.

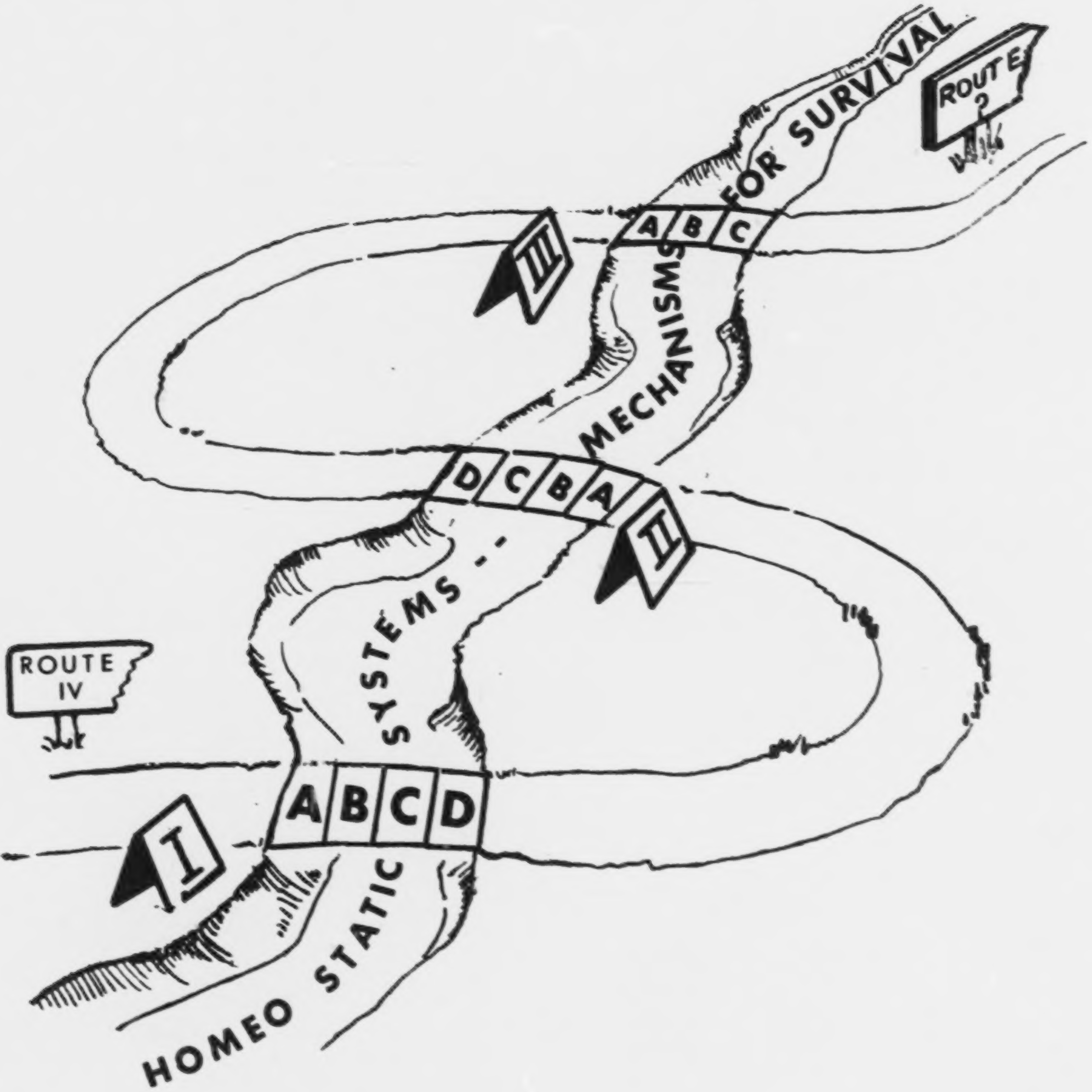
SCIENCE IV


ROUTE ?
FOR SURVIVAL
A B C
III
MECHANISMS
D C B A
II
SYSTEMS --
ROUTE IV
A B C D
I
HOMEO STATIC

MECHANISMS FOR MATTER – ENERGY INTERACTIONS IN LIVING ORGANISMS

MATTER - ENERGY RELATIONSHIPS OF THE ELECTRON

SCIENCE IV


ROUTE ?
FOR SURVIVAL
A B C
III
MECHANISMS
D C B A
II
SYSTEMS - -
ROUTE IV
A B C D
I
HOMEO STATIC

INTRODUCTION

PROBLEMS OF SURVIVAL INHERENT IN LIVING SYSTEMS

MATTER-ENERGY INTERACTIONS RELATING TO LIVING SYSTEMS

LIFE AND THE LAWS OF THERMODYNAMICS

THE CONCEPT OF HOMEOSTASIS

Homeostatic Systems - Mechanisms for Survival

INTRODUCTION

Problems of Survival Inherent in Living Systems

Matter-Energy Interactions Relating to Living Systems

Life and the Laws of Thermodynamics

The Concept of Homeostasis

HOMEOSTATIC SYSTEMS
MECHANISMS FOR SURVIVAL

INTRODUCTION:

This course is about some of the physical and chemical laws governing the functions and activities of living organisms. These laws are simple modifications of the same laws that govern all matter.

Traditionally it was once considered impossible to discover such laws - the excuse being made that living things are so complex as to evade all of our attempts to understand their functions. Consequently, quantitative analysis was strictly limited to non-living matter.

As time went on, it was found that physical and chemical measurements could be made just as well on living matter, provided that the appropriate apparatus could be designed and operated to extract the appropriate data from the living matter. In other words, the basic problem in understanding the functions of living matter was, and continues to be a technological one.

By analyzing the various data gathered from living matter and by considering the architecture and chemical composition of the particular cells forming the building blocks of the kind of living matter under investigation, scientists eventually were able to propose models for possible mechanisms governing the functions of living matter. As time went on, these models were refined to fit new situations and new data thus improving our understanding of the mechanisms.

Today, this understanding is by no means complete - and this course cannot give you all the answers; however, by concentrating on the topics that allow points of contact to be made between physical laws and biological laws, it is hoped that you will develop your own ideas about some of the life functions and perhaps become interested in designing some models for yourselves.

Reading:	Part II.	Baker-Allen, Matter, Energy and Life pp 3-7; pp 42-44; pp 47-52
	Part III.	Baker-Allen, Matter, Energy and Life pp 53-58; pp 67-71 Dull, Metcalf and Williams, Modern Physics pp 270-280 Loewy and Siekevitz, Cell Structure and Function Chapter 2, "Life and the 2nd Law of Thermodynamics".
	Part IV.	L. L. Langley, Homeostasis, Preface and Chapters 1 and 2 R. W. Gerard, Unresting Cells , Chapt. 14, "Organism."

It is recommended that every student read this entire book sometime during the year. The ideas that the author presents are clarified by diagrams, illustrations, and analogies - and freed from complication by the omission of burdensome technical terms.

I. Problems of Survival Inherent in Living Systems

A. The Problem of Energy Capture and Its Transduction into Biologically Useful Forms

1. Specialization, Division of Labor, and Adaptability of Organs of Sensation

2. The Channeling of Bioelectrical and Biochemical Energy Along Specific Pathways

B. The Problem of Energy Storage Within the Organisms

1. In the Form of Information

a. Memory

b. Replication

2. In the Form of Fuel

a. Biosynthesis

b. Respiration

C. The Problem of Energy Utilization

- 1. Locomotion and Mass Transport
  - a. Mechanical Work Done on Environment
  - b. Mechnical Work Done on Internal Parts
  - c. Transmission of Biochemical Messages via Transport Systems
  - d. Chemical Work Done on Internal and External Environments
- 2. Biosynthesis and Respiration
- 3. Active Transport
  - a. Osmoregulation and Excretion
  - b. Concentration gradients
  - c. Polarity and Electrical Potentials
- 4. Replication, Growth, Development, Reproduction
  - a. Transmission of Chemical Messages
  - b. Mass Migration of Cells
  - c. Differentiation
  - d. Deposition of Materials

ENERGY FLOW THROUGH LIVING SYSTEMS

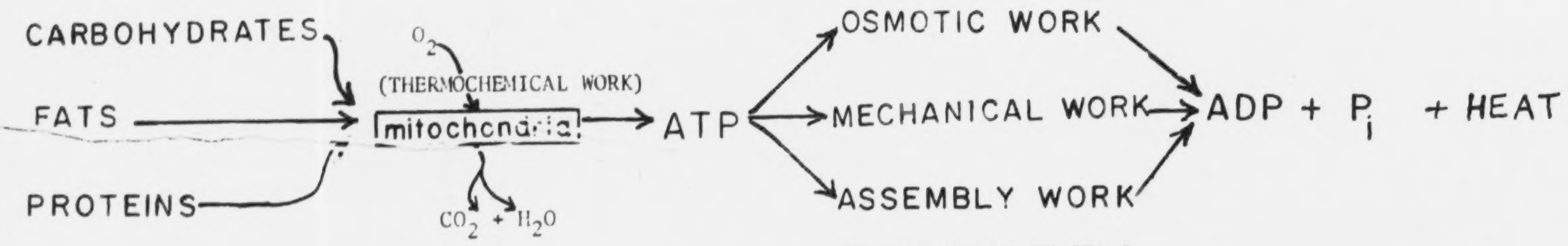
POTENTIAL FORMS OF ENERGY:

FUELS FROM THE ENVIRONMENT

CHARGED FORMS OF ENERGY: ACTIVATED INTERMEDIATES WITHIN THE CELL'S BIOCHEMICAL MACHINERY

ENERGY IN THE FORM OF WORK

SPENT FORMS OF ENERGY



TYPE OF WORK DONE BY THE ORGANISM	MECHANISMS WHICH MAKE THE WORK POSSIBLE	GENERAL NATURE OF CELLS ASSOCIATED WITH THESE MECHANISMS	ASSOCIATED SYSTEMATIC FUNCTIONS
THERMOCHEMICAL (also photo- and electrochemical)	Mechanisms for the Capture, Storage and Utilization of Matter and Energy	transducing absorptive storage metabolic	ingestion digestion assimilation fermentation respiration excretion
OSMOTIC (also Hydraulic)	Mechanisms for the Transport, Regulation and Exchange of Matter and Energy (transport of fluids and regulation of their contents)	transporting secretory excretory	circulation gas exchange ionic, osmo, thermo regulation secretion excretion
MECHANICAL (also osmo-and electrochemical)	Mechanisms enabling organisms to act and react (the physiological basis of behavior)	conductile contractile secretory	conduction contraction secretion excretion support
ASSEMBLY (also reproductive)	Mechanisms by which living matter (either cells, organisms or populations) propogates itself through space & time.	reproductive secretory	cell division reproduction growth de[illegible]pme[illegible]

II. Matter-Energy Interactions Relating to Living Systems

A. The availability of energy for life - ultimate sources

B. Life's dependence upon continuous energy flow - intermediate sources

C. Various energy-requiring activities of living organisms

D. The organism's dependence on energy for maintaining an internal state of orderliness

III. Life and the Laws of Thermodynamics

A. Introduction to Elementary Thermodynamics and the Concept of Entropy

1. A Laboratory Investigation of the Thermodynamics of a simple system

2. The forms of energy

a. mechanical

b. chemical

c. electromagnetic

d. Internal Potential and Kinetic Energy

1) Heat and temperatures

2) Units of heat energy

3) Specific heat

B. The Laws of Thermodynamics

1. The first law (E = Q-W)

   a. energy equivalences

   b. calorimetry

      1) the quantity of heat required to change temperatures

      2) the method of mixtures

   c. Hidden energy

      1) heat of fusion

      2) heat of vaporization

2. The second law

   a. Increased potential energy

   b. Entropy

      1) the ratio $S = {}^{Q}/T$

      2) order vs. disorder

INTRODUCTION TO ELEMENTARY THERMODYNAMICS

AND THE CONCEPT OF ENTROPY

All matter can exist in three states, the solid state, the liquid state and the gaseous state. We usually associate these states to a temperature range at a constant pressure. As energy is added to a solid, work is done on that solid to change it into a liquid. The same is true for the changing of a liquid into a gas.

We will qualify these ideas by putting an immersion heater into a calorimeter cup containing crushed ice. The relationship between Q, the number of calories of heat put into the calorimeter, and electric current is:

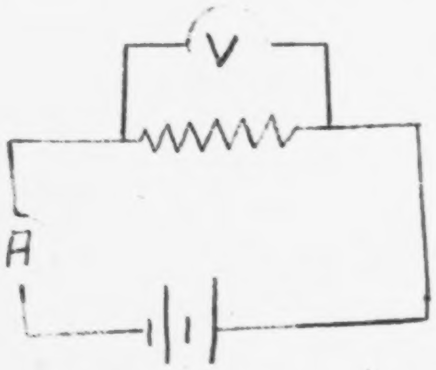
$$Q = \frac{W}{J} = \frac{VIt}{J}$$

where V is voltage, I is amperage & t is time in seconds. The proportionality constant J equals 4.19 joule/calory.

PROCEDURE:

Crush 100 grams of ice into an aluminum calorimeter cup and place the immersion heater into the cup. Put a thermometer (^{o}C) and cork into the hole in the cover. Make certain that the thermometer is sufficiently imbedded into the ice so that $T_i = 273^{o}K$.

Wire the immersion cup to a low voltage source in the following manner:



Start the low power voltage supply at 5 volts D.C. and the time clock simultaneously. Record the temperature of the water and ice mixture every 30 seconds. Make certain that you use the plunger on the cover to keep the mixture at a homogenious temperature. As the temperature reaches 10^{o} take readings at 5 minute (300 sec) intervals. Maintain this frequency of readings until the temperature has been at $100^{o}C$ for 15 minutes.

We now wish to graph the number of calories (Q) put into the calorimeter as a function of the temperature of the mixture. We see from our equation that:

$$Q = \frac{VIt}{J}$$

and therefore we can calibrate the number of calories for any set number of seconds. To avoid these many calculations, we note that since our 9 voltage, our amperage and J have remained constant for the entire experiment that we could call $\frac{VI}{J}$ another constant, say k. We can then say that $Q = kt$ or that Q is directly proportional to the time in seconds. We have as data the time in seconds so let us graph t in place of Q (they are proportional) against temperature. (t on y axis, T on x axis)

The slope of the t vs T graph is an indicator of the change of entropy of our system. Do you know why this is so?

DATA SHEET

Name ______________________

Science IV A Hour _____ 10

Date ______________________

Mass of ice =

Voltage = V =

Amperage = I =

T_i of ice and water mixture =

t	T	t	T	t	T	t	T	t	T	t	T	t	T	t	T

QUESTIONS

Name ______________________

Science IV A

Date ______________________

1. From your graph, t vs T, what do you note concerning the change in temperature when the ice is melting or when the water is boiling? What do you think is happening to the energy that we are putting into the system during these intervals? (Remember that according to the kinetic molecular theory, temperature is a measure of the average kinetic energy of the molecules)

2. From this experiment, what can you say concerning the degree of orderliness of the steam molecules compared to the ice molecules? How does the entropy and the degree of orderliness of any system compare?

3. The kinetic molecular theory maintains that temperature is a measure of the average kinetic energy of the system. Is your t vs T graph a straight line in the water phase of the experiment? What does this indicate about the distribution of of the energies concerned? How would you relate this to an entropy change?

C. The Apparent Violation of Entropy by Living Systems

1. Life and the second law of thermodynamics
   - a. The second law restated:
   - b. Entropy
     - 1) Defined as a measure of randomness of the energy of a system
     - 2) Definable in terms of probability
       - a) more probable vs. less probably states of matter
       - b) life as a less probably state of matter
   - c. The uniqueness of life in view of the second law
     - 1) the high degree of orderliness associated with living cells and organisms
       - a) orderliness at structure
       - b) orderliness of function (metabolic pathways)

2) The maintenence of orderliness requires effort

a) examples of energy expenditures

b) energy capture and utilization not 100% efficient

2. Energy Distribution with Respect to Life

a. the kind of work cells must do to maintain their high degree of orderliness

b. the capacities of cells for doing work

c. free energy, the total internal energy available for doing work

1) free energy defined

2) distribution of the total internal energy in any system

3) inevitable loss of work-producing capacity due to conversion of P.E. to K.E.

4) low degree of efficiency in utilizing P.E. for work as predicted by the second law:

3. The Total Internal Energy Available Within a System in Terms of Heat Content of Chemical Constituents

a. Heat content defined

b. Heat of reaction

c. Types of chemical reactions in view of ΔH:

1) exergonic reations

2) endergonic reations

d. Heats of formation and combustion

1) Heats of combustion at some common organic compounds in calories per mole. See Appendix

2) Heats at formation - for calculation. See Appendix.

3) Examples

e. Validity of the heat of reaction as a measure of the total internal energy. Does the amount of heat evolved correspond to the amount of work a system should yield?

4. The Total Internal Energy Available Within a System in Terms of ΔG.

a. The relationship between ΔG, ΔH and Entropy

ΔG not always equal to ΔH -

b. G as a measure of the degree of spontaneity for a given chemical reaction:

1) when ΔG is negative:

2) when ΔG is positive:

c. The sign of ΔG according to the second law:
ΔG must always be negative since a universal decrease in free energy is necessary for any chemical reaction to occur. This is true for the inanimate world and the animate world as well.

Possible ways of getting a negative ΔG:

1) exergonic reactions

2) endergonic reactions

3) positive entropy

18 4) Negative entropy

5. The Significance of a Negative $T\Delta S$ term in the free energy equation

   a. The possibility of a negative entropy means that there are particular chemical reactions that can increase orderliness

   b. That such chemical reactions can and do increase orderliness is not a violation of the second Law of Thermodynamics for the following reasons:

      1) The second law allows for an increase in orderliness provided that high grade potential free energy is supplied to the systems from outside.

      2) The free energy gained by a system in the process of increasing its orderliness is equal to (or less than if it is shared) the free energy lost by the supplying part of the universe.

3) The net G of the universe always remains negative even though negative entropy may exist in some of its systems

c. The ultimate destiny of life in our solar system in view of the second law:

1) As soon as the supply of free energy to a living system is cut off, that system proceeds spontaneously towards a greater state of disorder as do all other systems.

2) The ultimate source of free energy upon which life in our solar system depends comes from the sun.

Problems

Name ______________________________

Science IVA Hour _____

Date ______________________________

1. A mixture of ice and water, mass 200 g, is in a 100 g calorimeter, specific heat 0.200 cal/g°C. When 40 g. of steam at 100°C is added to the mixture, the temperature is raised to 60°C. How many grams of ice were originally in the calorimeter?

2. Calculate the change in entropy when 40 g. of ice at 0°C changes to 40 g. of water at 0°C. What can you say concerning the degree of order of the molecules in this change?

3. The overall efficiency of a boiler and steam turbine is 20%. If 50.0 lb of coal is burned each hour in the boiler, what is the horsepower developed? The coal has a heating value of 1×10^4 Btu/lb.

4. What must be the speed in m/sec of a snow ball at 0°C, if the snow ball is to be completely melted by its impact against the wall?

IV. The Concept of Homeostasis

A. Nature and Scope of the Concept

1. The Term Defined

2. Applicability to a Wider Variety of Fields

3. Implications and Universality of the Idea

B. Historical Perspective

1. Origin of the Idea

a. Egyptians

b. Hippocrates and the Greeks

2. Evolvement of the Idea Through the Work of 19th Century Physiologists

a. Pfluger - 1877 - German Physiologist

b. Fredericq - 1885

c. Charles Richet

d. Claude Bernard - 1843 - French Physiologist and father of the concept in that he was the first to employ the term as a generalization and recognize its universality

e. Walter B. Cannon - 1871-1945 - American Physiologist and and popularizer of the concept

C. General Principles Pertaining to Homeostatic Systems and the Function of Their Component Parts

1. Functions of Animate Control Systems as Analogous to Those of Inanimate Control Systems

a. The Science of Cybernetics

b. Feedback Mechanisms (servomechanisms)

c. Homeostatic Mechanisms

2. Model System

a. The Steady State vs. The Unsteady State

1. Internal Environment Maintained in a State of Near - Absolute Constancy, i.e., controllable

2. External Environment - High Degree of Variability Renders it Virtually Uncontrollable, Except When Small Parts of it are Isolatable within a Relatively Closed System

b. Component Parts of the Homeostatic Control System

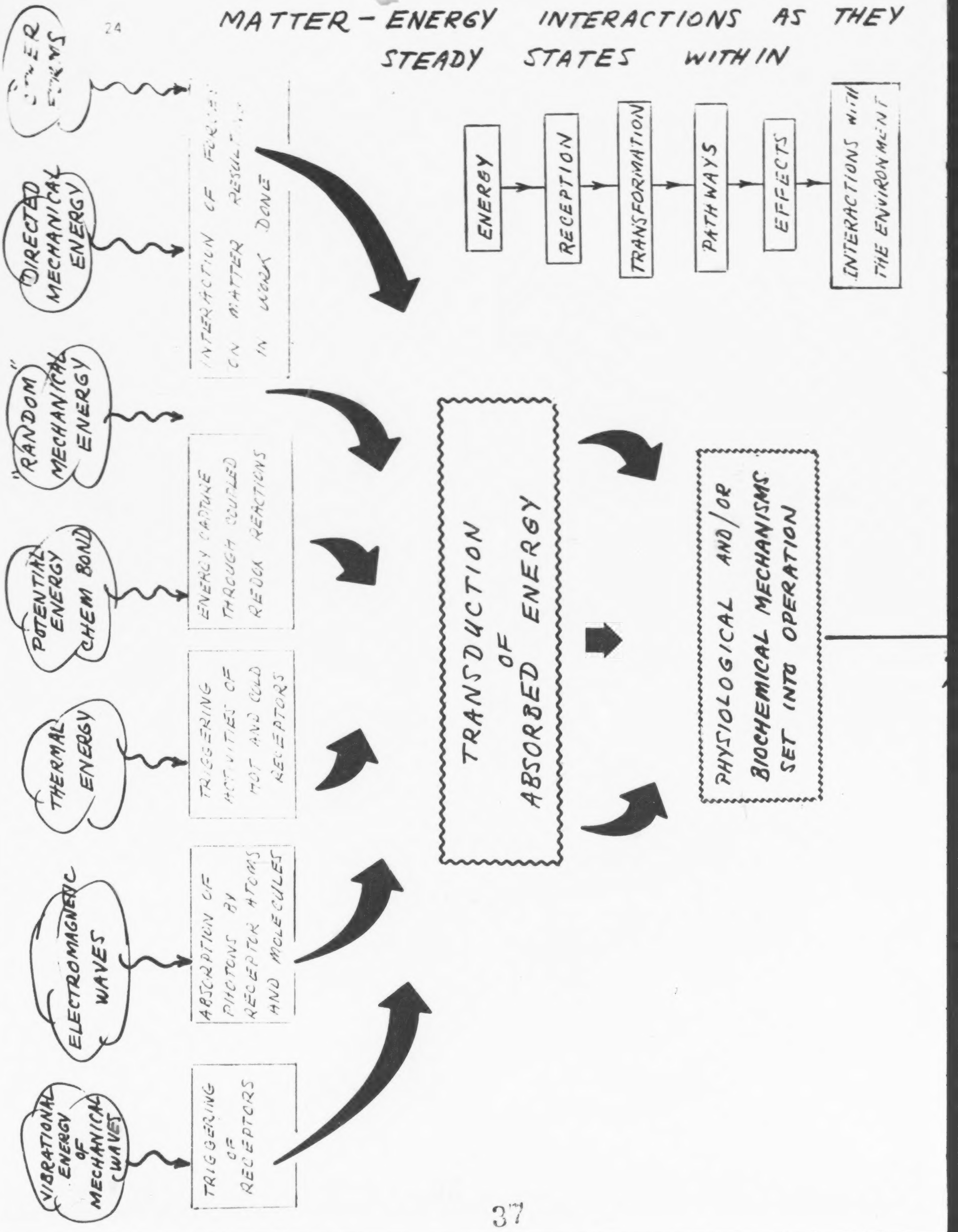
(1) Sensing Device - responds when the variable factor being controlled falls below the predetermined value

(2) Circuit - relays messages from the sensing device to the effector mechanism

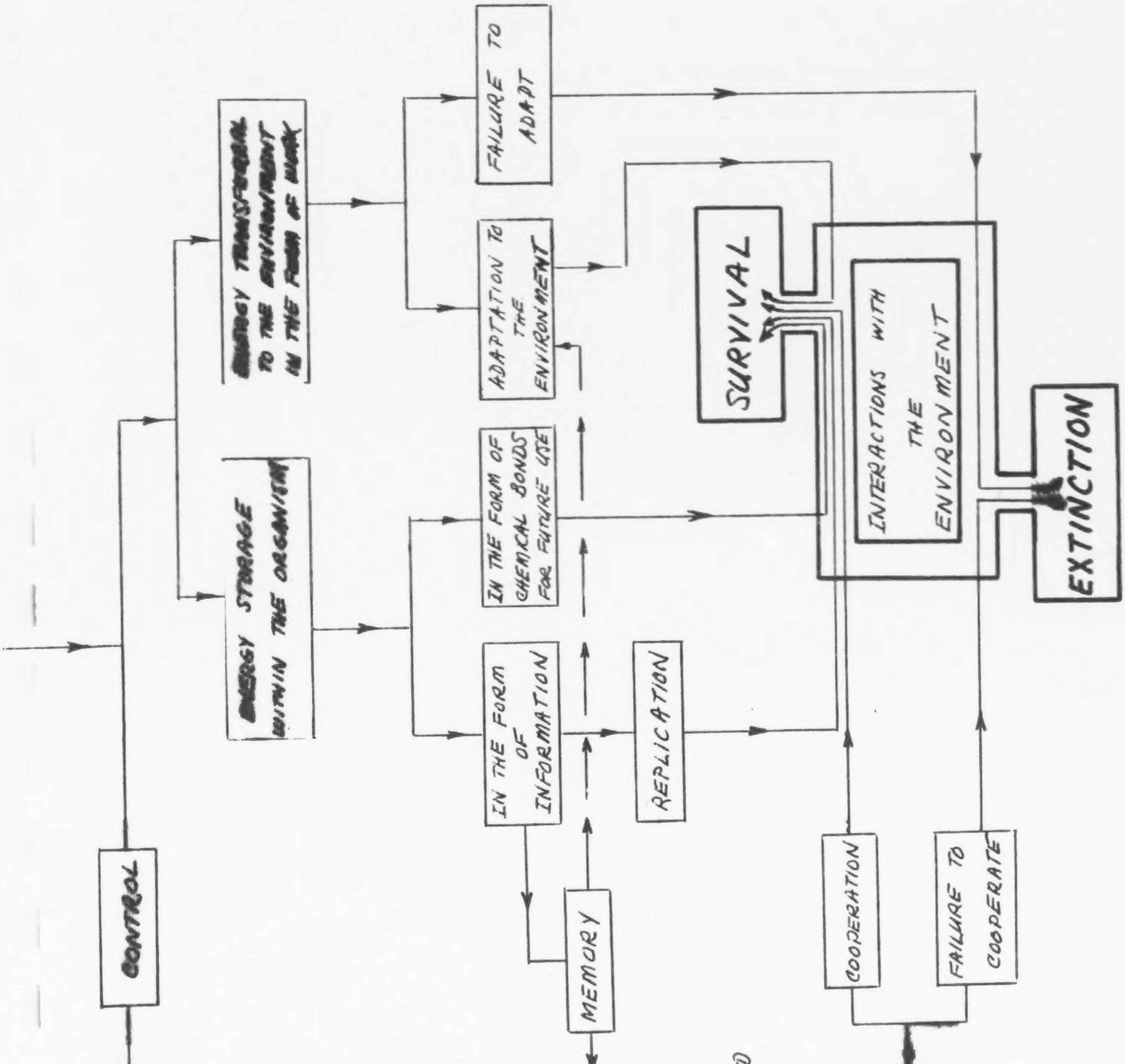
(3) Effector Mechanism - when activated by messages sent from sensing device, it responds in such a way as to correct for random fluctuations of the variable factor being controlled for within the internal environment

D. The Organism as a Steady - State System

MATTER - ENERGY INTERACTIONS AS THEY STEADY STATES WITHIN


VIBRATIONAL ENERGY OF MECHANICAL WAVES
TRIGGERING OF RECEPTORS
ELECTROMAGNETIC WAVES
ABSORPTION OF PHOTONS BY RECEPTOR ATOMS AND MOLECULES
THERMAL ENERGY
TRIGGERING ACTIVITIES OF HOT AND COLD RECEPTORS
POTENTIAL ENERGY CHEM BOND
ENERGY CAPTURE THROUGH COUPLED REDOX REACTIONS
"RANDOM" MECHANICAL ENERGY
DIRECTED MECHANICAL ENERGY
INTERACTION OF FORCES ON MATTER RESULTING IN WORK DONE
OTHER FORMS
TRANSDUCTION OF ABSORBED ENERGY
PHYSIOLOGICAL AND/OR BIOCHEMICAL MECHANISMS SET INTO OPERATION
ENERGY
RECEPTION
TRANSFORMATION
PATHWAYS
EFFECTS
INTERACTIONS WITH THE ENVIRONMENT

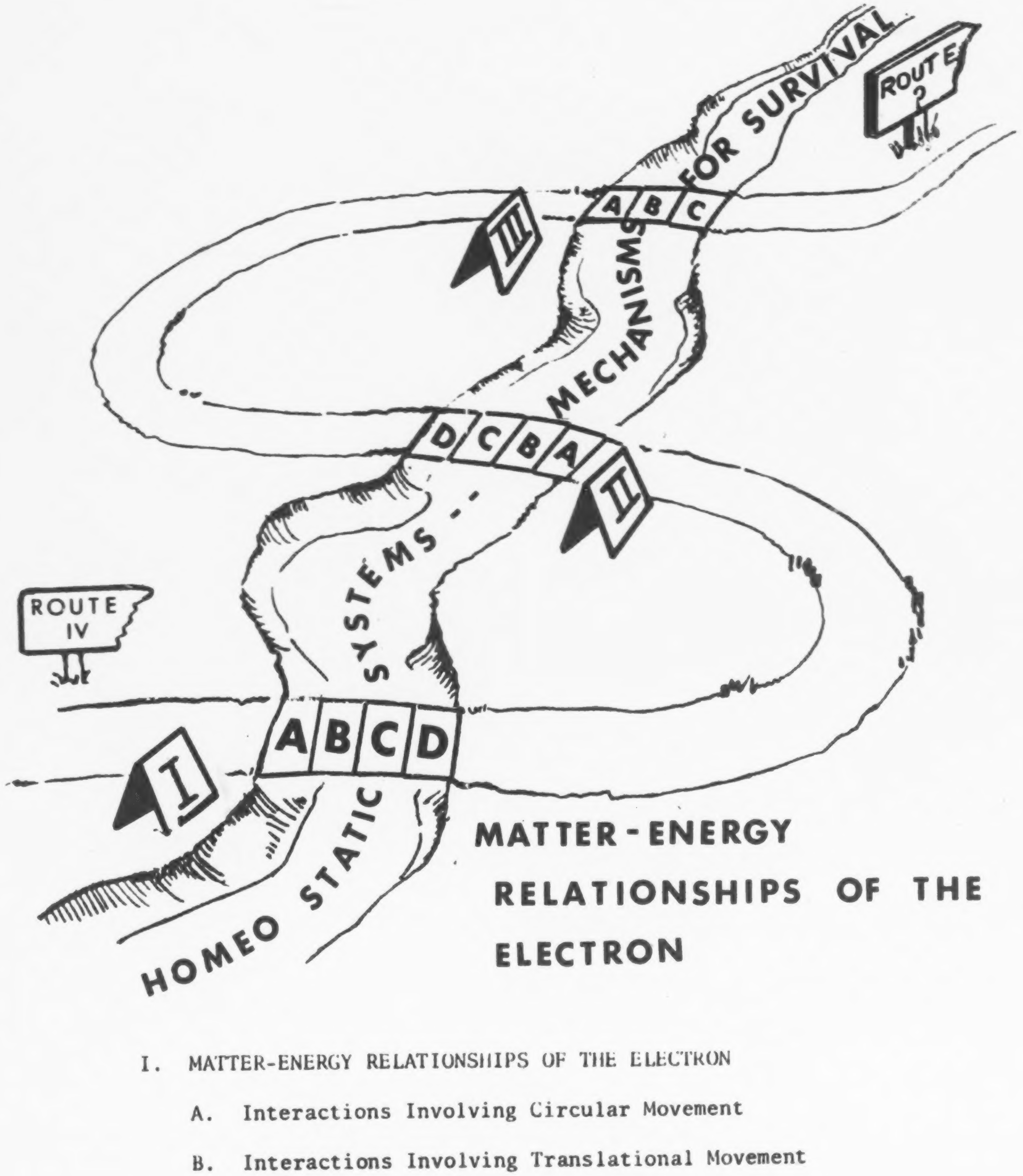
PERTAIN TO THE MAINTENANCE OF THE LIVING ORGANISM


CONTROL
ENERGY STORAGE WITHIN THE ORGANISM
ENERGY TRANSFERRAL TO THE ENVIRONMENT IN THE FORM OF WORK
IN THE FORM OF INFORMATION
IN THE FORM OF CHEMICAL BONDS FOR FUTURE USE
ADAPTATION TO THE ENVIRONMENT
FAILURE TO ADAPT
REPLICATION
MEMORY
SURVIVAL
INTERACTIONS WITH THE ENVIRONMENT
EXTINCTION
COOPERATION
FAILURE TO COOPERATE
SELECTIVITY
THOUGHT DIRECTED ACTIVITY
PERCEPTION THOUGHT REASON
THOUGHT DIRECTED ACTIVITY
SELECTIVITY
?

The living being is stable. It must be so in order not to be destroyed, dissolved, or disintegrated by the colossal forces, often adverse, which surround it. By an apparent contradiction it maintains its stability only if it is excitable and capable of modifying itself according to external stimuli and adjusting its response to the stimulation. In a sense it is stable because it is modifiable - the slight instability is the necessary condition for the true stability of the organism.

Charles Richet

SCIENCE IV


ROUTE IV
I
A B C D
HOMEO STATIC
SYSTEMS --
II
D C B A
MECHANISMS
III
A B C
FOR SURVIVAL
ROUTE ?
MATTER-ENERGY
RELATIONSHIPS OF THE
ELECTRON

I. MATTER-ENERGY RELATIONSHIPS OF THE ELECTRON

   A. Interactions Involving Circular Movement

   B. Interactions Involving Translational Movement

   C. Interactions Between Electric and Magnetic Fields

Matter-Energy Relationships of the Electron

A. Interactions Involving Circular Movement

Magnetic Characteristics of Matter

Forces in Magnetic Fields

Magnetic Forces

Interactions Involving Circular Forces

Resource Material

Required Reading: Modern Physics, Chapter 21, p. 462-472

Recommended Reading:
Basic Science Series #200-8, Chapter 1, Magnetism: A field of Force
Magnets, by Francis Bitter
PSSC Physics, Chapter 30, The Magnetic Field, p. 522-528

QUESTIONS FOR CONSIDERATION:

1. What is magnetic pole strength? What factors effect the magnitude of magnetic pole strength? Define a "unit pole".

2. Discuss the relationship between magnetism and electric charge. How does this relationship relate to the "Domain Theory of Magnetism"?

3. Describe a current theory to account for the earth's magnetism.

4. What is a "line of force"? Do lines of force actually exist? Discuss some properties of lines of force.

5. How is the law of magnetic force related to Coulomb's Law for electrostatic forces and to the Law of Universal Gravitation?

6. Define magnetic field strength. How can one measure the magnitude of a magnetic field? What factors influence the intensity of a magnetic field?

7. Define magnetic torque and magnetic moment.

A. Interactions Involving Circular Motion

MAGNETIC CHARACTERISTICS OF MATTER

1. A review of the basic structure of matter

2. A review of the Basic Energy Forms

   a. Potential Energy

   b. Kinetic Energy

   c. The Conservation of Energy

3. The interaction of matter and energy which results in change

   a. Force

29

4. Theory of Magnetism

   a. Magnetism - a property of charge in motion

      1) orbital motions

      2) spin

   b. Magnetic Domains

   c. Magnetic Poles

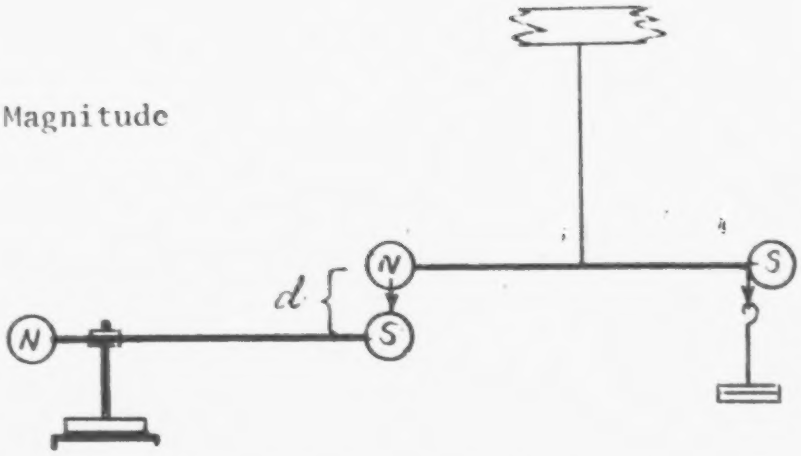
5. Magnetic Pole Strength

a. Detection of pole strength

b. Measurement of pole strength

6. Forces Between Magnetic Poles

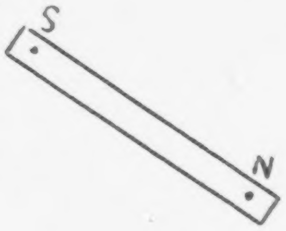
   a. Factors That Influence the Magnitude of the Force Between Poles



   b. Coulomb's Law for Magnetism

Force F_1	Distance	Fd^2

7. Magnetic Fields - devices used which help explain magnetic forces acting at a distance.



FORCES IN MAGNETIC FIELDS

8. Lines of Force

   a. Properties of Lines of Force

   b. Magnetic Flux Density

9. Interaction of Forces in Magnetic Fields

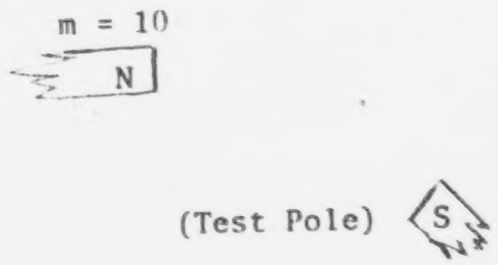
   a. Magnetic Field

   b. Resultant Forces in Magnetic Fields

      1) Effect of the Earth's Magnetic Field

      2) Neutral Points

   c. Magnetic Field Strength



RF(dynes)	Pole Stren.	RF/m

      1) Magnetic Field Strength at Any Point

      2) Earth's Magnetic Field Strength in Madison Area

Laboratory Problem

INTERACTION OF FORCES IN MAGNETIC FIELDS

INTRODUCTION

The lines of force associated with magnetic fields of an isolated bar magnet do not form the smooth curves and neat geometric patterns usually pictured as described in books. This sort of non-distorted field probably does not exist anywhere in nature. Magnetic fields ranging outward from the poles of a magnet interact with other magnetic fields. Since the earth itself exhibits the properties of a huge magnet and has a magnetic field which encompasses the entire globe, it is not possible to escape the influence of the magnetic forces associated with the earth's magnetism.

The magnetic field strength in the vicinity of a magnet is inversely proportional to the square of the distance from the poles. The intensity of the earth's magnetic field in Dane County is about equivalent to the field strength of a magnet with a pole strength of 800 unit poles, at a distance of three feet. If you were to explore the magnetic field of such a magnet at this distance from its poles you would find it extremely difficult to distinguish between those lines of force associated with the bar magnet and those which are a part of the earth's magnetic field..

PROBLEM

1. Plot the resultant magnetic field surrounding a bar magnet and locate the two points where the resultant field strength is zero.
2. Calculate the pole strength for both the North and South poles of the bar magnet.

THEORY

Magnetic field strength is a vector quantity having the same direction as the resultant force, $\underleftarrow{H} = \overleftarrow{R}F/m$.

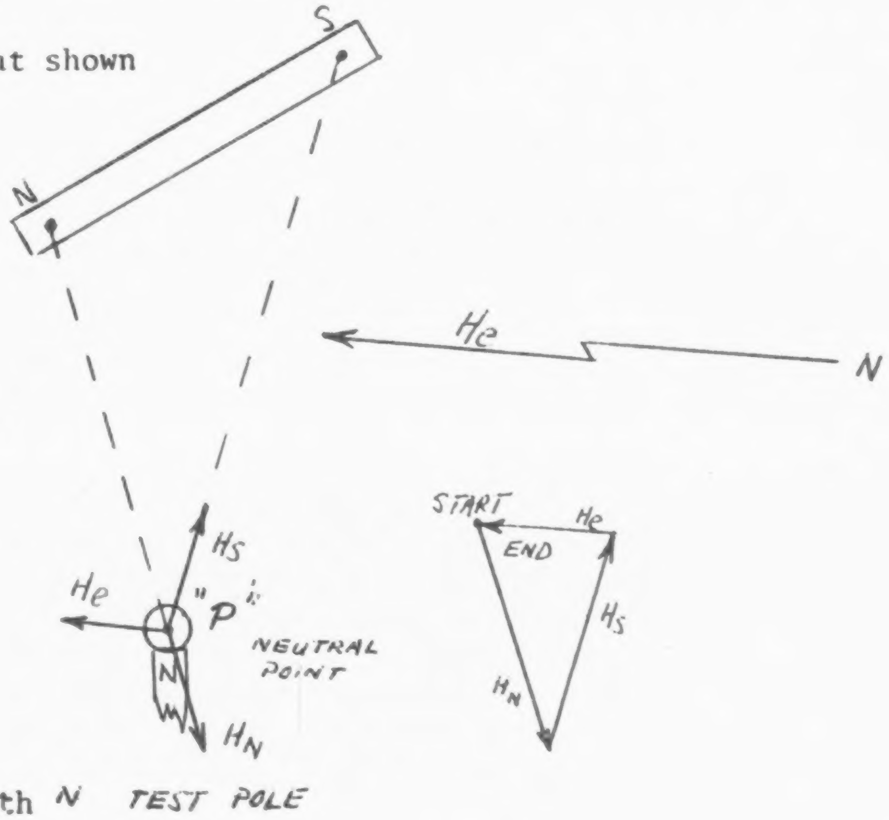
Whenever two magnetic field "overlap" the interaction of forces that takes place causes the magnetic field to become distorted. The amount of distortion depends upon the relative direction and magnitude of the interacting forces. In the area very close to the magnet the force of the earth's field has little effect on the lines of force associated with the bar magnet. Further away, where the field strength of the bar magnet drops off to values on a par with those in the earth's field, the distortion will be very significant.

For every bar magnet, interacting with the earth's magnetic field, two neutral points exist. That is, two points where the relative strength and direction of the interacting forces is such that the resultant field strength is zero.

At a "neutral point" such as that shown at the right, the total force experienced at that point is zero, because the horizontal component of the earth's field, H_e, is exactly equal in magnitude, but opposite in direction, to the field at "P" caused by the bar magnet.

The North ple of the bar magnet will produce a magnetic field strength "H_N" at the neutral point "P" in the direction of NP - the South pole produces a magnetic field strength "H_S" in the direction of PS.

The resultant of these two vectors, plus "H_e" gives the resultant magnetic field strength of the magnet and the earth at the point P.



When any line R is drawn in the figure, parallel to H_e, the relative lengths of R, H_N, and H_S are fixed, since the triangles formed are similar.

If the value of H_e is known, the magnitude of the vectors H_N and H_e may be determined by vector analysis.

The values for the pole strengths of the magnet may be determined from the vector diagram.

Magnetic field strength is $H = m/d^2$; by the following derivation:

$$F = \frac{m_S m_T}{d_T^2} \quad ; \qquad H_S = \frac{F}{m_T} = \frac{m_S \cancel{m_T}}{d_T^2 \cancel{m_T}} = \frac{m_S}{d_T^2}$$

Since the value for H_e in this area is equal to 0.16 oersteds, the value for H_S and H_N can be determined by vector analysis. The distance from the poles to the neutral point can be measured, and the distance between the poles can be calculated. The center of a pole is considered to be 1/12 of the length of the magnet in from the end.

PROCEDURE

Fasten a large sheet of paper to the desk top with tape. Place the bar magnet with its axis parallel to the length of a paper near the center of the sheet. Outline the magnet on the paper and indicate its polarity and the direction of the earth's field. Place a small compass near the north pole of the magnet and make dots as near each end of the needle as possible and in line with it. Move the compass in the direction in which its north pole points until the south pole is above the dot previously made at the north pole and make another dot at the north pole in its new location.

Continue until the series of dots leads to the south pole of the bar magnet or near the edge of the paper. Draw a smooth curve through the points and indicate, by arrows, the direction of the field.

In a similar way trace other lines of force until the field is clearly represented on all sides. Successive lines may be originated from any point near the permanent magnet. Continue the "mapping" until lines have been traced far enough from the magnet to show the undisturbed field of the earth.

Two places should be found where the direction taken by the compass needle is indeterminate; places where the compass needle does not seem to assume any specific direction. These positions are called "neutral points", and the region in this vicinity should be mapped with great care. The field near these points is very weak and is zero at the precise point of neutrality.

Do not use a pencil which is encased in metal until it has been determined that the metal does not effect the compass readings.

Locate both neutral points and use the magnetic map to calculate the pole strength for the North and South pole of the magnet.

Current theories of magnetism suggest that the pole strength at the North and South pole centers of a magnet must be equal. Thus, if the two neutral points are precisely located, the calculated values for the North and South pole strengths would be equal.

ANALYSIS OF DATA AND CONCLUSION

Compute the values for the North and South pole strengths of the bar magnet based on the location of the neutral points. Determine the percentage difference between these values and also the average value for the pole strength of the bar magnet. Show all vector diagrams and equations on the map which represents the resultant field.

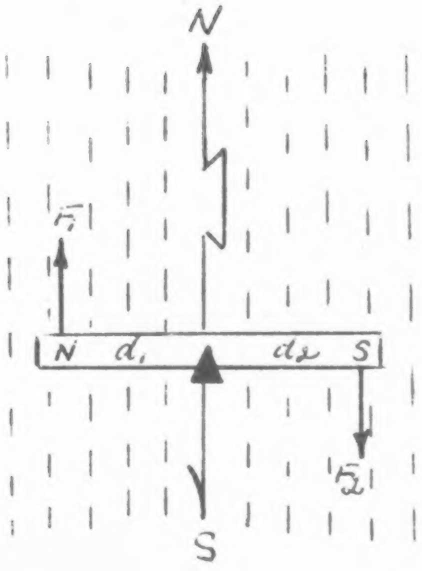
QUESTIONS

1. Do lines of force represent lines of equal force; that is, does a particular line of force pass through a series of points where the magnetic field strength is constant?
2. Explain why, within certain regions of a resultant magnetic field, a compass needle suddenly reverses its direction 180° as the compass is made to follow a specific line of force outward from the pole of the magnet.

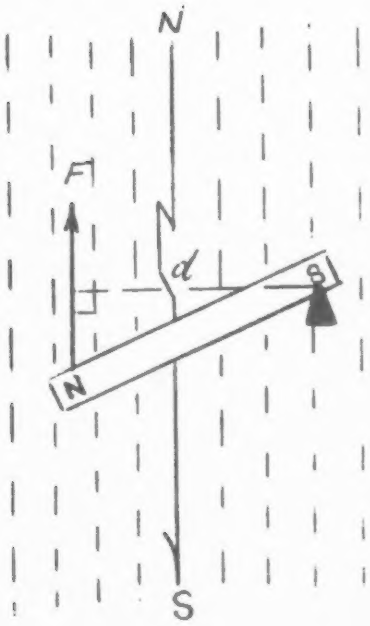
MAGNETIC TORQUES

10. Magnetic Torque

    a. Parallel Force Field


N
F_1
N
d_1
d_2
S
F_2
S

    b. Non- Parallel Fields



11. Magnetic Moment

Problem Assignment

Name ____________________
Science IVA Hour ___
Date Due ________________

MAGNETIC FORCES

1. A north magnetic pole having a strength of 30 units is placed 9 centimeters away from another north pole of a strength of 180 units. Determine the force of repulsion between them.

2. Two bar magnets, each 8 centimeters long, with a pole strength of 24 units, are placed end to end with their North poles 4 centimeters apart.
   a. Determine the resultant force on one of the magnets.
   b. Determine the resultant force on one of the magnets if they were placed side by side and parallel to each other at a distance of 6 centimeters. Both magnets have their North poles pointing in the same direction.

3. Determine the resultant force on a North magnetic pole having a strength of 30 units when it is located 20 centimeters from the North pole and also 20 centimeters from the South pole of a magnet which is 20 centimeters long. The pole strength of the magnet is 400 unit poles.

4. Two North magnetic poles having a strength of 40 and 90 units respectively, are placed 12 centimeters apart. Determine the magnetic field strength at a point 4 centimeters from the 90, and 10 centimeters from the pole of strength, 40 unit poles.

5. Determine the torque on a bar magnet which is placed with its axis perpendicular to the direction of a magnetic field of strength 20 oersteds. The length of the magnet is 6 centimeters and the strength of its magnetic poles is 15 units.

6. A certain bar magnet has a magnetic moment of 650 units. If the distance between the poles is 15 centimeters, what is the magnetic pole strength of the magnet.

7. Calculate the torque on a bar magnet having a length of 20 centimeters and a pole strength of 50 units when placed in a magnetic field having a strength of 12 oersteds. The axis of the magnet is such that it makes an angle of 20 degrees with the direction of the earth's field.

8. A bar magnet is placed with its axis parallel to the magnetic meridian and with its North magnetic pole pointing North. A neutral point is found to be 10 centimeters from the magnetic, on the perpendicular bisector of the axis. The distance between the magnetic poles of the magnet is 6 centimeters. If the earth's magnetic field strength at the neutral point is 0.16 oersteds, what is the pole strength and the magnetic moment of the magnet?

B. Interactions Involving Translational Motion of the Electron

Electrical Properties of Matter

Electric Charge

Electric Potential

Forces Between Charged Bodies

Electric Field

Direct Current

INTERACTIONS INVOLVING THE TRANSLATIONAL MOTION OF THE ELECTRON

Resource Material

Required Reading:	Modern Physics, Chapter 18, Electrostatics, pp. 381-406
Recommended Reading:	Basic Science Series, # 200-8, Chapter 2. "Electrostatics - Charge at Rest", pp. 23-47 PSSC Physics, Chapter 27, "Some Qualitative Facts About Electricity", pp. 443-459 Chapter 28, "Coulombs Law and the Elementary Electric Charge", pp. 462-482

QUESTIONS FOR CONSIDERATION:

1. What is electric charge? How is electric charge detected? Describe the units used to measure electric charge.

2. Discuss the meaning of electrical potential. When does an electrical potential exist? Why is the earth considered to be a body with zero electrical potential?

3. What factors determine the magnitude and direction of forces that exist between charged bodies?

4. What is meant by electric field strength? Why is the electric field strength at any given point in space, under the influence of a charged body, constant?

5. What is the relationship between the electrical potential between charged bodies and the amount of work that must be done in moving an electric charge about in an electric field?

6. What is the charge on an electron equal to? How was this value determined?

7. What is meant by electrical capacitance? What factors influence the ability of a conductor to "store" an electric charge?

8. What is the difference between an electrical conductor and an electrical insulator?

9. What is the difference between static electricity and current electricity?

10. What does the term, "electric current", describe? Describe the units used to measure electric current. How does electric current differ from voltage?

B. Interactions Involving the Translational Motion of the Electron

1. Electrical Properties of Matter

a. Basic Assumptions in Atomic Theory Which Describe the Electrical Properties of Matter

b. Historical Background - Discoveries Leading to the Development of Theories About the Nature of Electricity

1) Thales (640 B.C. - 546 B.C.)

2) William Gilbert (1544 - 1603)

3) Otto Van Guericke (1602 - 1686)

c. Classification of Matter on the Basis of Electrical Properties

1) Conductors

2) Non-Conductors

3) Semi-Conductors

2. Electric Charge

   a. The Nature of Electric Charge

      1) Definition of Charge

      2) Franklin's Theory

   b. Methods of Producing Electric Charge

      1) Conduction

      2) Induction

   c. Methods of Detecting Electric Charge

   d. Transfer and Distribution of Electric Charge

      1) the earth as a conductor

      2) electrical potential

3. Electric Potential Difference

a. Definition

1)

2)

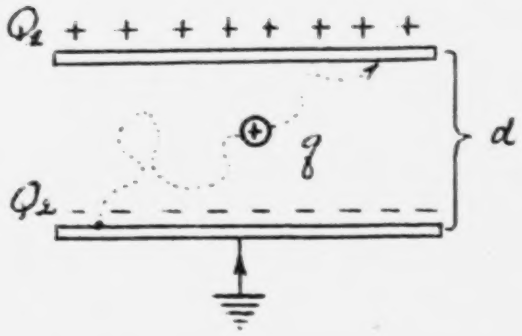
b. Units

1) e.s.u. (cgs)

2) practical (MKS)

POTENTIAL DIFFERENCE

INTRODUCTION:



In describing the properties of charged objects it is frequently necessary to know something about the work done in moving a charged object from one point in space to another.

Suppose that two plates are arranged as shown at the right. The top plate is given a + charge and the bottom plate is connected to the ground. Indicate, on the drawing, the distribution of charge for such a condition.

q	$w = F \cdot d$	$\frac{w}{q}$

Consider a small object, with a + charge, placed between the plates. This object would be attracted to the negative plate and be repelled by the positive plate. This produces a resultant force upon the body in the direction of the negative plate.

In order to raise the + charged body, q, in the direction of the + plate, a force equal to RF but opposite in direction would have to be exerted upon the body, If the force is used to move the charged body from the - plate to the + plate the work done would be equal to F x d (F//d).

The ratio of work done in moving a charge between two point, divided by the charge is very useful relationship in describing the properties of electricity. This physical quantity is given the name, POTENTIAL DIFFERENCE and the symbol V

$V = \frac{w}{q}$, where w is the work done in moving a charge q from one point to another.

When a + "test charge" q, moves from a point A to B in the region of an electric field about a charged body work is done. If the body is also + charged work must be done on q. If the body is - charged work is done by q. In either case the POTENTIAL DIFFERENCE between A and B is equal to the work done divided by the charge on q.

As a small "test charge" is brought from an undefined distance toward a charged body the intensity of the electric field encountered by the test charge increases and the force acting upon the moving charge increases in accordance with Coulomb's Law.

Exercise

Name ______________________
Science IV A Hour ____
Date Due ______________________

POTENTIAL DIFFERENCE BETWEEN CHARGED BODIES

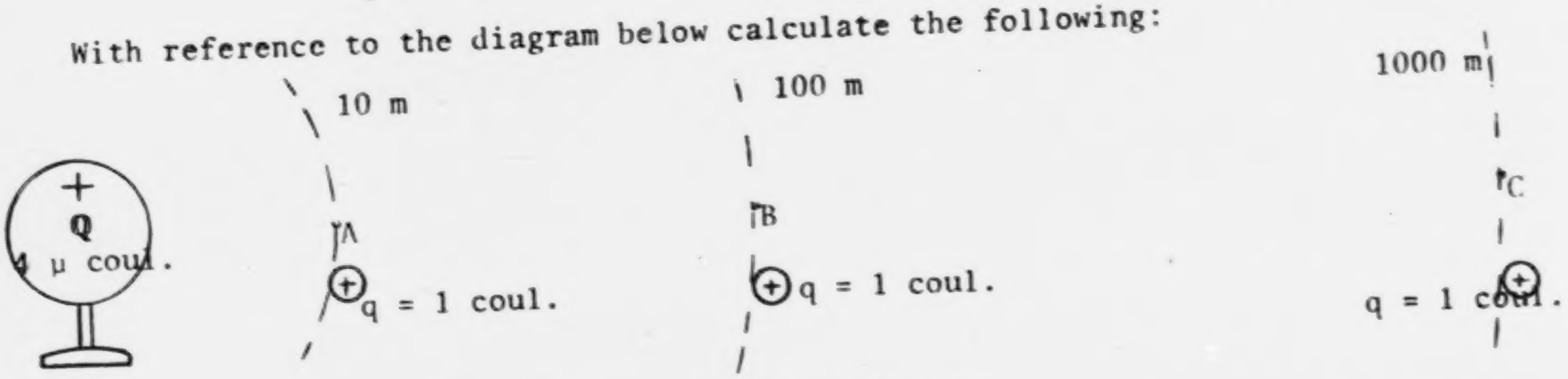
In describing the work done when the test charge moves toward the charged body, the distance which is decreasing from infinity to 0, is being multiplied by a force which is increasing from 0 to infinity. Consequently the work done in moving a charge from infinity to a point "A" near a charged body, is equal to:

$\int_{\infty}^{r}$ F x d; where F = $\alpha\ Qq/r^2$ and r is the distance from Q to "A".

The equation for the work done in moving a charge from infinity to a point "A" then becomes:

$$w = \frac{\alpha\ Qq}{r}$$

With reference to the diagram below calculate the following:



1. The work required to bring q from infinity to:
   - a. point C
   - b. point B
   - c. point A
2. The work required to move q from:
   - a. point C to B
   - b. point C to A
3. The potential difference between:
   - a. C and B
   - b. C and A
4. On the basis of potential difference and charge, calculate the work done in moving charge q from:
   - a. C to B
   - b. C to A
5. How is the work done in moving a charge from one point in space to another related to the path taken?
6. A potential difference of 600 volts is applied to two parallel metal plates that are spaced 2 cm. apart. What is the electric field strength in MKS units between the plates? What force would be exerted on a charge of 10^{-8} coul. placed anywhere between the plates?

Laboratory Investigation

THE ELECTRICAL PROPERTIES OF MATTER

INTRODUCTION:

All matter is composed of fundamental particles which are electrically charged. Electric charge is an undefined physical quantity. Like time, length and force (or mass), electric charge cannot be defined but it can be experienced directly via the senses and it can be measured.

It is a natural tendency for all matter to be electrically neutral, that is, to maintain an equality between the number of + protons and - electrons. However, it is possible to cause - electrons to be added to or taken away from a body and disturb the electrical equilibrium of the system. When this happens the system is said to be electrically charged. If the system has lost electrons it is positively charged, when a system gains electrons it becomes negatively charged.

When a charged body is brought near an uncharged conductor a separation of charges occurs, actually a movement of electrons in the uncharged body. The displacement of electrons as a result of the influence of a charged body near, but not in physical contact with a conductor is called "electrostatic induction". If a conductor is momentarily grounded, while in the presence of a charged body a charge, opposite in sign to that of the charged body, will remain on the conductor. This process is called charging by induction.

Often the foregoing phenomena are explained on the basis of the repulsion and attraction of like and unlike charges respectively. However, it is more desirable to base the explanation on the fundamental idea of "electrical potential".

Electrical potential may be described as the factor which governs the flow of electrons (electricity) between two bodies, or between two points in space. No electrons can move from one point to another unless there is a difference in electrical potential, that is, a difference in the magnitude of the electric charge between the points sufficient to drive the electrons along the conductor.

The electrical potential of a body depends upon a number of things: its charge, its capacity to hold a charge, and its position relative to neighboring charges. The presence of a body with a negative charge has the effect of lowering the electrical potential of all neighboring charges. The presence of a body with a positive charge raises the electrical potential of all surrounding bodies.

The electrical potential between any two points in space varies with the distance between the points and with the magnitude of the electric charge which resides at each point. The potential at any point within the boundaries of a spherical or cylindrical conductor is the same everywhere so long as the conductor is not actually transferring electrons.

One extremely important aspect of the theory of electrical potential has to do with the earth and all matter physically attached to it. The earth is so large compared to isolated systems on its surface that it is regarded as an inexhaustable source of electrons, or a limitless "sink" into which electrons can be poured without changing its electrical potential. At the same instant that electrons are being taken from the earth at one location, electrons are being returned to the earth at some other location. The result of this type of exchange is that the electrical potential of the earth, in total, remains unchanged. One can consider the earth to be somewhat like a non-profit "world bank" for electrons. An electron exchange goes on constantly as a result of deposits and withdrawals all over the world, but the books always balance. In total, the number of electrons being withdrawn are always equal to the number being returned and consequently the potential of the earth is always zero. This idea of regarding the earth as having a constant zero potential is fundamental to our understanding of modern electrical theory.

PURPOSE OF THE INVESTIGATION:

Our purpose in this experiment is to investigate the phenomena of electric charge which are basic to an understanding of the electrical nature of matter. Specifically we will be concerned with:

a. the production and transfer of electric charge by conduction and induction methods
b. the detection and identification of electric charge by use of the gold leaf electroscope
c. the distribution and retention of charge on various types of conductors.

PROCEDURE:

Each of the investigations described should be performed two or three times and the results noted and discussed by members of the group. The experiment report will consist of diagrams which show a quantitative distribution of charge on the various conductors. Represent a neutral electroscope with three + charges and three negative - charges. Represent all charged bodies by showing an excess of one + or - charge as the case may be. When electrons move along a conductor represent the direction of the motion by use of arrows.

PRECAUTIONS:

1. The gold leaf electroscope is a very sensitive instrument capable of detecting extremely small differences in electrical potential. Do not bring a highly charged body in direct contact with the instrument since a sudden excess charge will tear the gold leaves apart.

While using the electroscope maintain a ground connection between the case and the earth.

When you are through using the instrument, charge it slightly and replace the cap.

2. Do not touch the knob of a Leyden Jar condenser without grounding it first.

3. Handle all equipment carefully and with respect. Do not touch the surfaces of conductors and insulators any more than is necessary.

Laboratory Investigation

Name ____________________

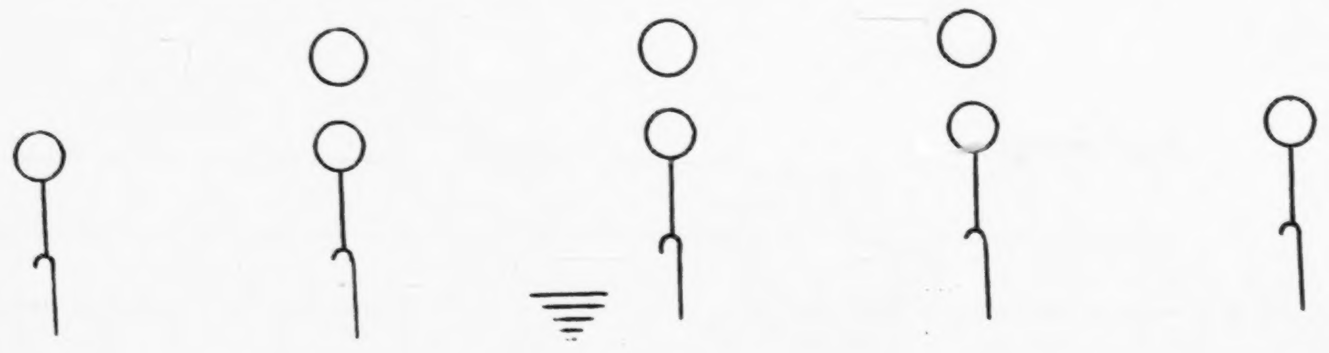
Science IA Hour ______

Date ____________________

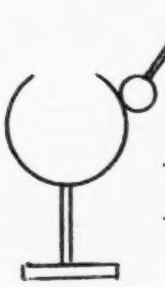
THE ELECTRICAL PROPERTIES OF MATTER

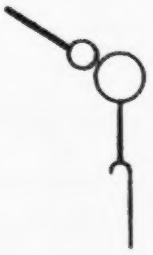
PART ONE: PRODUCTION AND TRANSFER OF ELECTRIC CHARGE BY CONDUCTION AND INDUCTION METHODS

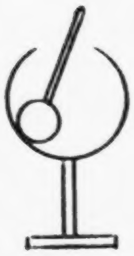
1. Ground the case of the electroscope to the gas pipe with a fine copper wire. Charge a hard rubber rod by buffing its surface with fur or wool. Charge the electroscope by INDUCTION. Note, carefully, the behavior of the leaves during each step in the procedure. Complete the diagrams below, illustrating each step of the procedure. Also, indicate the "charge" and "potential" of the electroscope for each step of the procedure.

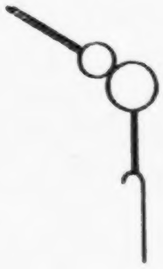


2. Charge the spherical conductor by bringing it near the Van de Graaf generator. Touch an uncharged proof plane to the outside of the sphere and then touch the proof plane to an uncharged electroscope. If the leaves diverge determine the sign of the charge on the electroscope. Repeat these operations several times, touching different points, both on the outside and the inside of the hollow sphere. Illustrate the results with a diagram and summarize the results with a statement describing the distribution of charge for a hollow conductor.



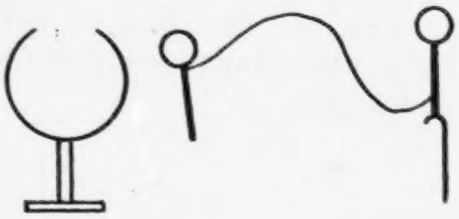






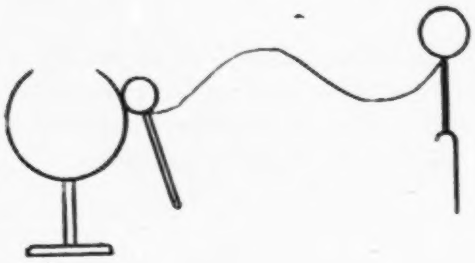
Statement: ______________________________

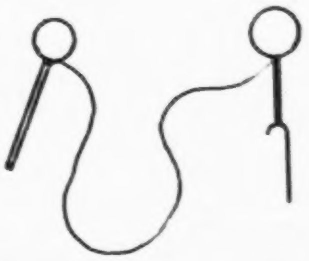
3. Connect the proof plane to the electroscope with a fine copper wire. Make sure that the proof plane and the electroscope are initially uncharged, then bring the proof plane near the charged sphere. Be careful to prevent the wire from touching your hand, the table top, or anything else. Determine the sign of the charge on the sphere. Determine the sign of the charge on the leaves of the electroscope. Complete the sketch, showing the distribution of charge on the sphere, the electroscope, and the proof plane. Indicate the charge and the potential for the electroscope.



Name ______________________

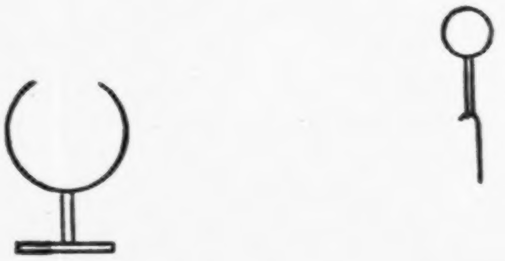
Next, carry the proof plane closer to the sphere and finally touch the outside surface of the sphere with the proof plane. Make a diagram showing the charge distribution and electron flow. Remove the proof plane and make a second sketch showing the final charge and potential on the electroscope.



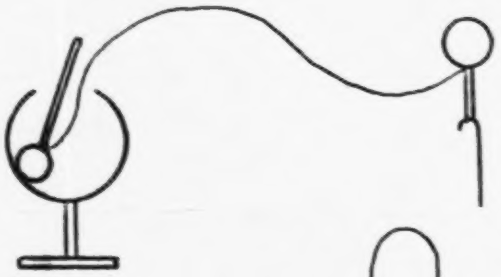


4. Repeat the operations in part 3, but this time carry the proof plane inside the opening of the sphere. Be careful not to touch the edge of the opening with the proof plane or with the wire. Make a set of three drawings to show the charge distribution on the sphere, the proof plane and on the electroscope for the following situations:

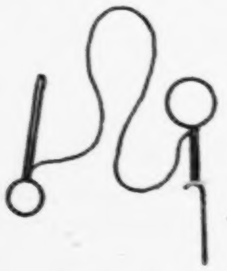
a. proof plane inside the sphere without any contact between the plane and the sphere



b. proof plane in contact with the inside surface of the sphere



c. proof plane removed, after contact with the interior of the sphere

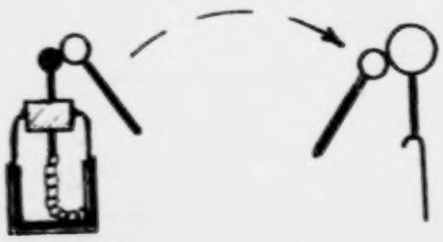


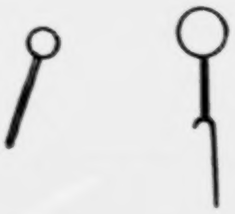
Make a concluding statement summarizing what you have learned about the distribution of a charge on a body.

PART TWO: POTENTIAL DIFFERENCE AND DISTRIBUTION OF CHARGE

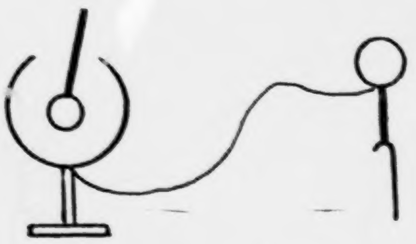
1. Charge the Leyden Jar by holding the base in your land and placing the knob in contact with the sphere on top of the Van de Graaf generator. The jar serves as a container for a supply of charge which can be carried to your table and used as needed during the course of this part of the experiment.

   Transfer a small amount of charge to the electroscope by touching the proof plane to the knob of the Leyden Jar and then to the electroscope. Make a sketch showing the distribution of charge on the Leyden Jar, the proof plane, and the electroscope.



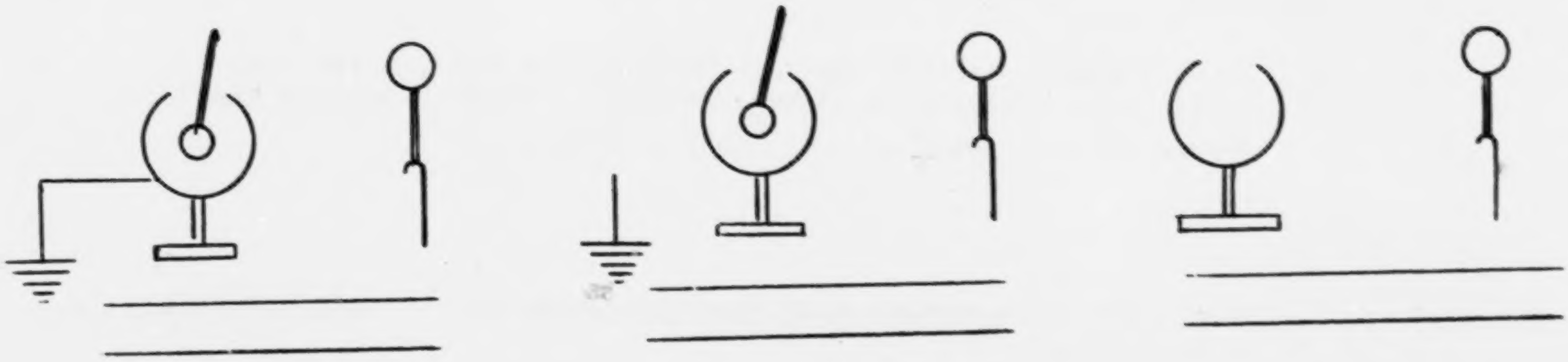


2. Connect the uncharged electroscope to the insulated hollow sphere which will serve as your "ice pail". Give the proof plane the same charge as that on the knob of the Leyden Jar and introduce it into the hollow sphere. Be careful not to make contact with the sides of the spherical conductor. Test the sign of the charge on the electroscope. Remove the plane carefully. Note the behavior of the electroscope. Illustrate the action with a sketch and describe the movement of charge in the systems.

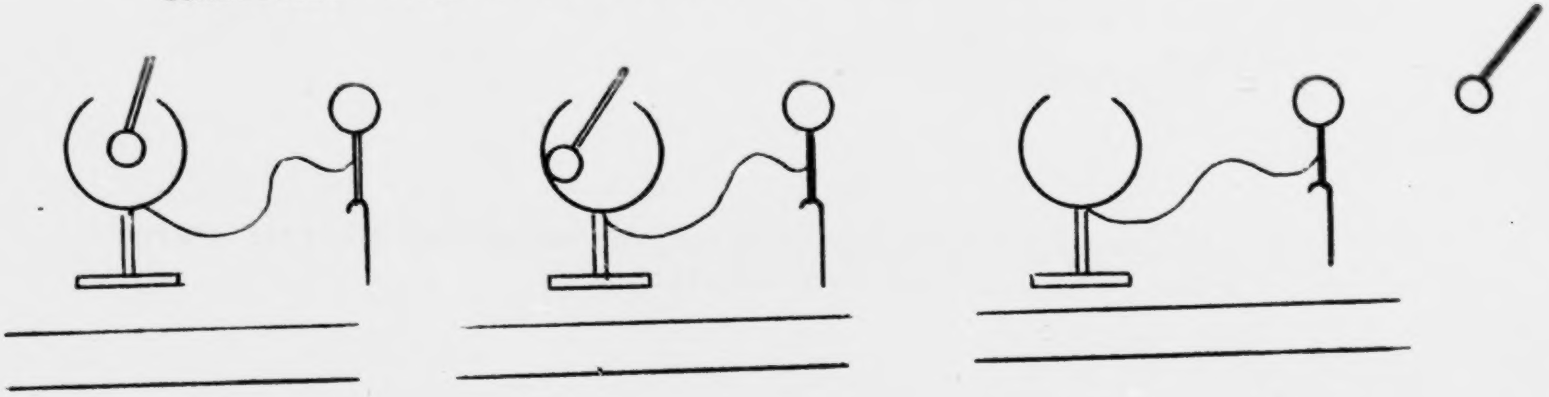


3. Recharge the proof plane and again introduce it into the hollow conductor without making contact with its surfaces. Ground the spherical conductor. Break the ground and then remove the proof plane. Investigate the sign of the charge on the electroscope. Discharge the electroscope and the conductor. Diagram the electron motion observed.

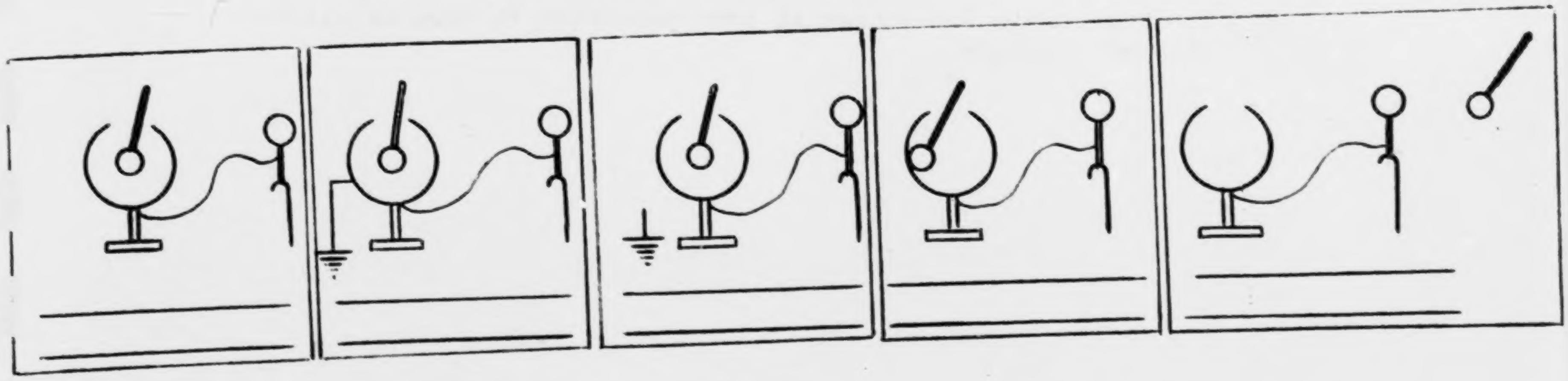
Name ______________________________



4. Recharge the proof plane and place it inside the conductor. Now let it make contact with the inside surface and note the divergence of the leaves of the electroscope. Remove the proof plane and determine the charge on the electroscope. Determine the sign of the charge on the proof plane. Discharge the electroscope and the spherical conductor. Diagram the results.



5. Recharge the proof plane again and introduce it into the spherical conductor without making contact. Ground the conductor. Break the ground. Touch the proof plane to the inside of the conductor and note carefully the behavior of the leaves of the electroscope. Remove the proof plane. Diagram the results.



QUESTIONS:

1. A small proof plane is touched first to the outside and then to inside of a charged spherical conductor. Does it acquire the same charge in each case?

   Is it, while in contact with the conductor, at the same potential in each case?

2. If the leaves of an electroscope are slightly diverged, how could one tell, without touching it, whether the divergence was due to rigidity of the leaves or due to a slight charge?

3. Identify four basic ideas about the nature of electric charge illustrated in this investigation.

4. Is it possible for a body at zero potential to have an electric charge? Explain.

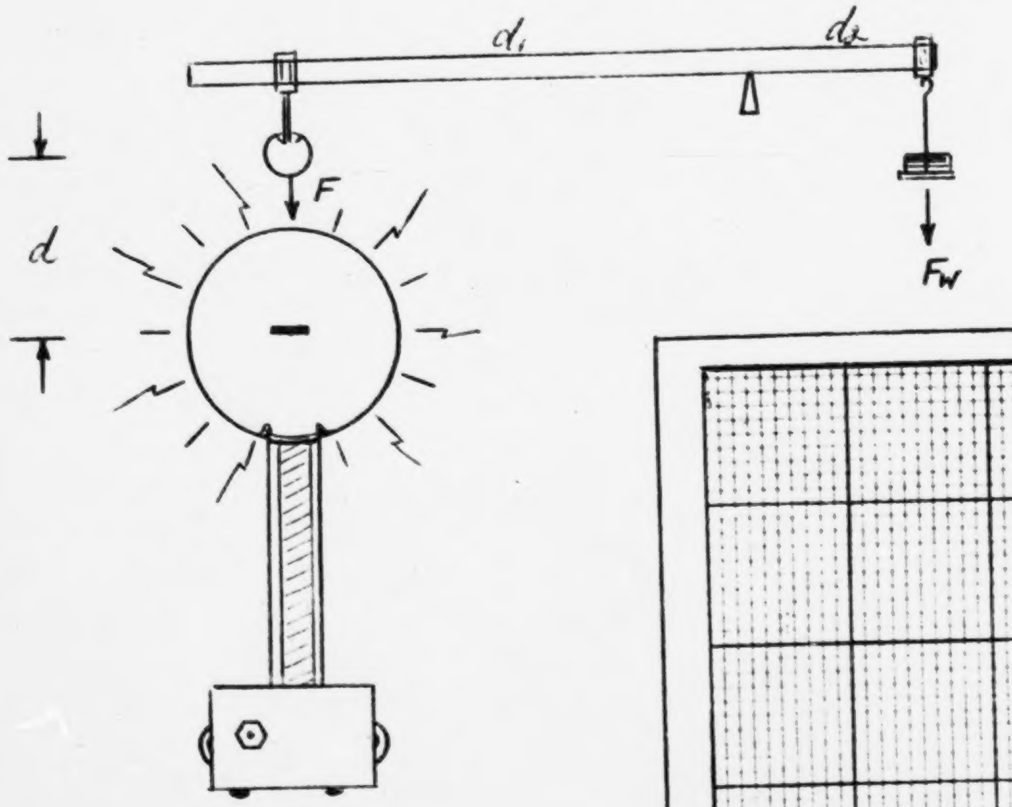
4. Forces Between Charged Bodies

a. Conditions which Result in Forces Between Charged Bodies

1) Attraction

2) Repulsion

b. Force - Distance Relationship Between Charged Bodies



d	F_W	F	d^2

$$TMA = \frac{d_1}{d_2}$$

$$F = \frac{F_w \cdot d_2}{d_1}$$

5. Coulomb's Law (1748) Charles Augusten de Coulomb
    a. Deviation of Working Equation
    b. Proportionality Constant, α
        1) CGS Absolute
        2) MKS Absolute
6. Electric Charge
    a. Undefined Physical Quantity
        1) Methods of Detection
        2) Symbolization
    b. Units of Measurement
        1) Coulomb (MKS) Absolute
        2) Statcoulomb (CGS) Absolute

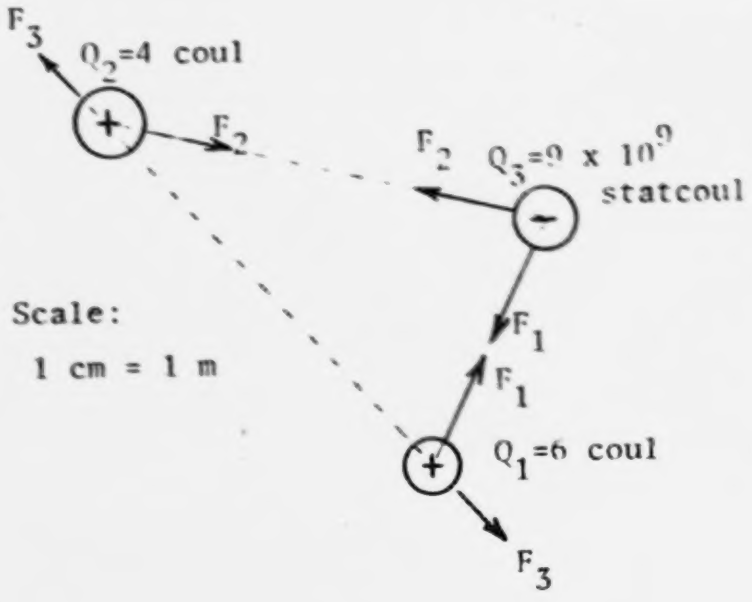
7. Interaction of Forces Between Charged Bodies

Coulomb's Law provides a method for determining the force on any charged object which is under the influence of forces associated with other charged objects.

The magnitude of the force between any two charged bodies is calculated by Coulomb's Law. The summation of forces requires vector analysis.

Assume three charged bodies in space as shown. Calculate the resultant force on each.

$$F = \frac{\alpha Q_1 Q_2}{d^2}$$


F_3
Q_2=4 coul
+
F_2
F_2
Q_3=9 x 10^9 statcoul
−
Scale:
1 cm = 1 m
F_1
F_1
+
Q_1=6 coul
F_3

F_1 =

F_2 =

F_3 =

RFQ_1 =

RFQ_2 =

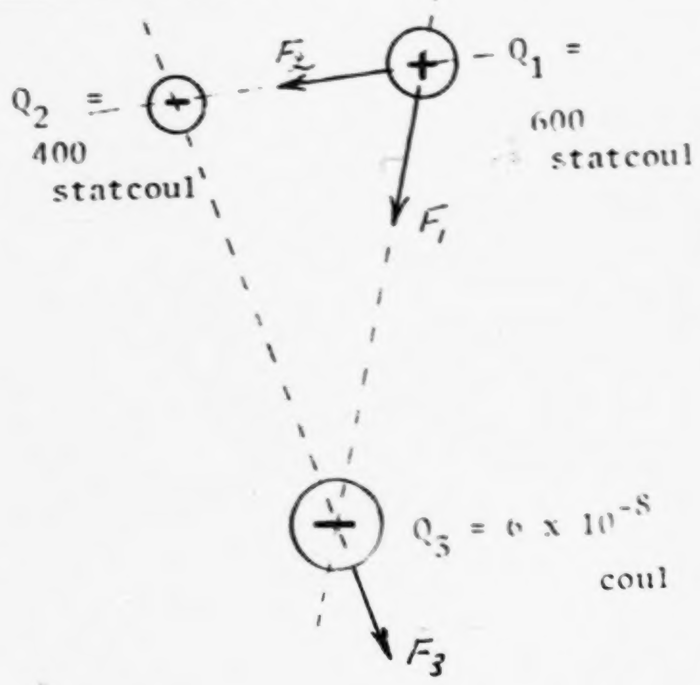
RFQ_3 =

Exercise

Name ____________________
Science IIIA Hour ___
Date Due ________________

INTERACTION OF FORCES BETWEEN CHARGED BODIES

Calculate the resultant force on each of the charged bodies in the following system.


Q_2 = 400 statcoul
F_2
Q_1 = 600 statcoul
F_1
$Q_3 = 6 \times 10^{-8}$ coul
F_3

Scale: 1 cm = 1 m

F_1 = __________
F_2 = __________
F_3 = __________

RFQ_1 = __________ _____
RFQ_2 = __________ _____
RFQ_3 = __________ _____

Problem Assignment

Name ____________________
Science IIIA Hour ______
Date Due ________________

ELECTROSTATIC FORCES

1. Calculate the force that will be experienced by a body which has a positive charge of 150 statcoulombs when it is 8 centimeters from an object with a positive charge of 240 statcoulombs.

2. Two equal negative charges repel each other with a force of 350 dynes when placed 4 centimeters apart. What is the magnitude of the charge on one of the bodies which is charged?

3. The force of attraction between two charged objects is 500 dynes. The electric charge on one object is 400 μ coulombs, the other has a charge of 2×10^{-2} coulomb. Calculate the distance between the two bodies.

4. An object with a charge of 300 statcoulombs (negative) is located 8 centimeters from a body with a charge of 200 statcoulombs (positive). Determine the electric field strength at a point 12 centimeters from the positive charge and 4 centimeters from the negative charge.

Calculate the potential difference between the charged bodies and this point in the electric field which surrounds them.

5. The work done in carrying a charge of 8 statcoulombs from the earth to a point near a charged sphere was found to be 20 ergs.

   a. Determine the potential difference between the earth and that point.

   b. If the point was located 5 centimeters from the charged object, what was the magnitude of the charge on the object?

6. Calculate the work that can be done by an object having a negative charge of 0.3 coulombs when it moves from a position 400 centimeters distant to a position 30 centimeters distant from an object with a positive charge of 60 coulombs. Express your answer in Practical and M.K.S. units.

8. Electric Fields - devices used to explain electrical forces acting at a distance.

   a. Definition

      1)

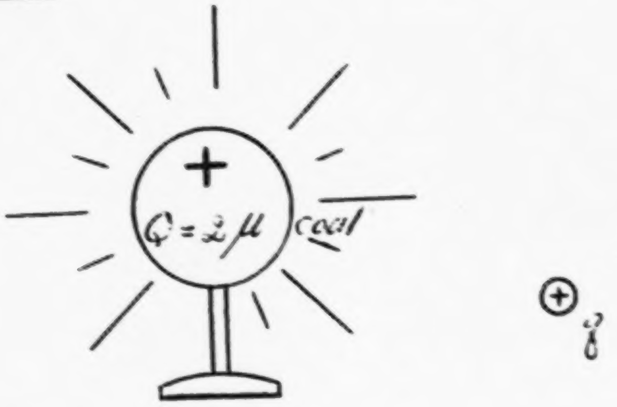
      2)

   b. Units

      1) e.s.u. (CGS)

      2) practical (MKS)

ELECTRIC FIELD STRENGTH



In attempting to understand the electrical nature of matter it is helpful to picture a charged body as being in a state of "stress" and that the space surrounding the body contains an electric field composed of electric lines of force issuing out from the body in all directions.

Consider a positively charged body with a charge of 2 μ coul, isolated in space. If a "test charge" of 1 coul + (q) is brought into the region of the electric field it will experience a force of repulsion in accordance with Coulomb's Law.

Assume that the "test charge" is one meter from the charged body and that it is given, successively, charges of 1, 2, 3, 4, and 5 coulombs. Calculate the resultant force on (q) in nts.

Charge on q (coul.)	Resultant F on q (nts)
1 coul	
2 coul	
3 coul	
4 coul	
5 coul	

It is seen that the resultant force and the charge on q, for each case, may be shown to represent a constant. This constant RF/q is a characteristic of that particular point in space where q is located with reference to Q. It describes the intensity of the electric field at this point.

This constant represents an important physical quantity in electricity and is given the name ELECTRIC FIELD STRENGTH and the symbol E

$E = \frac{F}{q}$, where F is the resultant force on a charged object at a certain point, and q is the charge.

Units:

e.s.u.	electrstatic units	(CGS)
practical units		(MKS)

Exercise

Name ____________________

Science IV A Hour ____

Date Due ____________________

ELECTRIC FIELD STRENGTH

1. A charge of two statcoulombs placed in an electric field experiences a force of 0.04 nts. Calculate the electric field strength at this point.

E = __________

2. Find the magnitude and direction of the electric field strength at a point 16 centimeters from a body with a charge of (positive) 5.12×10^{-3} μ coulombs.

RF = __________ ________

DIRECT CURRENT

Resource Material

Required Reading: Modern Physics p. 454-487,

9. Sources of Direct Current

   a. Electric Charles in Motion

   b. Continuous Currect

      1) Chemical

         a) Oxidation-Reduction Reactions

         b) Electron Transfer & Predicting Reactions

         c) Measuring Half-Cell Potentials

2) **Photoelectric**

3) **Thermelectric**

4) **Piezoelectric**

5) **Bioelectric**

ELECTROCHEMICAL CELLS

INTRODUCTION:

You have observed a number of oxidation-reduction reactions in which the oxidizing and reducing agents were in direct contact with each other. In these reactions electrons were transferred directly from reducing agent to oxidizing agent. Oxidation-reduction reactions may also be made to take place when the agents are not in direct contact. In this case, the electrons are transferred from the reducing agent through a wire to the oxidizing agent. This arrangement, called an electrochemical cell permits the system to do electrical work as the electrons are transferred from one agent to another.

The reactions take place at the poles (electrodes) of the cell. The redox equation for the overall cell reaction may be expressed as the sum of two half-cell reactions. For example, the reaction

$$Zn(s) + Cu^{+2} \longrightarrow Zn^{+2} + Cu(s)$$

may be obtained by adding the following two half-cell reactions.

anode (oxidation): $Zn(s) \rightleftharpoons Zn^{+2} + 2e$

cathode (reduction: $Cu^{+2} + 2e \rightleftharpoons Cu(s)$

At the anode, zinc atoms dissolve leaving electrons on the metal and forming zinc ions which go into the solution. At the cathode, copper(II) ions are removed from solution as they accept electrons and deposit on the cathode as copper atoms. The two solutions maintain their electrical neutrality when positive ions (K^+) migrate from the salt bridge into the cathode compartment, and negative ions (Cl^-) migrate into the anode compartment. The flow of electrons from anode to cathode may be detected with an instrument called a galvanometer (sensitive ammeter), but we will use a voltmeter to measure potential difference between the electrodes.

In this experiment we will construct several electrochemical cells, examine the helf-cell reaction at each electrode, measure the potential difference between the half-cells with a voltmeter, and investigate some factors which affect the voltage of the cell.

PROCEDURE:

1. Prepare or obtain 200 ml of 1 M $Zn(NO_3)_2$ and 200 ml of 1 M $Cu(NO_3)_2$ solution. Place the solutions in separate 250 ml beakers.
2. Construct and fill a U-tube with 1 M KNO_3 solution. Stopper both ends with a loose cotton plug. Invert the U-tube into the two beakers. The U-tube full of a conducting solution acts as a salt bridge which keeps the solutions electrically neutral by allowing ions to migrate from one beaker to the other.
3. Place a copper strip in the copper solution and a zinc strip in the zinc solution.
4. Obtain a 0-3 volt D.C. voltmeter with 0 at the left side. Use wires with alligator clamps to connect the electrodes to the terminals (posts) of the voltmeter. Connect the leads so that the needle deflects to the right

when the circuit is completed. Read the voltage of the cell and record the value in the table shown below. Look at the posts on the voltmeter to identify which is the positive and which is the negative electrode. Record this information in the table. The electrons will flow through the external circuit from the negative electrode(anode) to the positive electrode (cathode). In the table, identify the anode and cathode for each cell you test.

Cell	Voltage	Negative electrode (anode)	Positive electrode (cathode)	Theoretical standard-state voltage
$Zn\|Zn^{+2}(1M)\|\|Cu^{+2}(1M)\|Cu$				
$Pb\|Pb^{+2}(1M)\|\|Cu^{+2}(1M)\|Cu$				
$Fe\|Fe^{+2}(1M)\|\|Cu^{+2}(1M)\|Cu$				
$Cu\|Cu^{+2}(1M)\|\|Ag^{+}(1M)\|Ag$				
$Zn\|Zn^{+2}(1M)\|\|Ag^{+}(1M)\|Ag$				

5. Replace the beaker containing the zinc solution with one containing a lead strip in a 1 M $Pb(NO_3)_2$ solution. Save the zinc half-cell for later use. Use a different salt bridge for the lead-copper cell if one is available. Read and record the voltage of this cell.
6. Replace the beaker containing the lead strip with one containing a strip of iron in a 1 M $Fe(NO_3)_2$ solution. Read and record the voltage.
7. Replace the beaker containing the iron strip with one containing a silver strip in 1 M $AgNO_3$ solution. Read and record the voltage.
8. Construct a cell using the zinc and silver half-cells and measure the voltage.

10. The Ampere

a. André Marie Ampere

b. Definition of one ampere

c. Relationship of one ampere to electric charge

C. The Interactions Between Electric and Magnetic Fields

Electromagnetic Induction

Electromagnetic Radiation

ELECTROMAGNETIC INDUCTION

Resource Materials

Required Reading:	Modern Physics: PP. 472-476 and pp. 487-493
Recommended Reading:	Basic Science Series, #200-8, Chapter III, "Electromagnetism: Charge in Motion", pp. 529-534 PSSC Physics, Chapter 31, pp. 548-562 Lives in Science, Michael Faraday, pp. 127-140 Joseph Henry, pp. 141-153 Biographical Encyclopedia of Science and Technology, Asimov, Hans Christian Oersted, p. 180

QUESTIONS FOR CONSIDERATION:

1. What is an electric current? When a conductor carries an electric current, what is actually happening?

2. Discuss the relationship between the direction of an electric current along a conductor and the direction of the magnetic field that is set up.

3. What factors effect the intensity of the magnetic field which surrounds a conductor carrying an electric current?

4. What is meant by an induced current?

   Under what conditions is an electric current induced to flow along a conductor?

5. What is the difference between "induction" and "self induction"?

   Discuss the role of self induction in transformer operation.

6. Discuss Lenz's Law as it relates to induced current.

7. Is "work" done when an electric current is induced to flow along a conductor? Explain and illustrate.

8. What is the difference between maghetism and electricity?

   What is the difference between electrostatic forces and magnetic forces?

Laboratory Investigation

MAGNETISM AND ELECTRICITY

INTRODUCTION

In our study of electrostatics we were primarily concerned with methods of producing differences in electrical charge and with the interaction of forces between stationary and moving charged bodies. We have observed in the charging and discharging of electroscopes and condensers that an electric charge can move through a conductor. In each of these cases the flow of charge in a conductor was a momentary motion which continued only as long as a difference in the electrical potential (charge) between the bodies existed.

If one were to maintain a continuous difference in the magnitude of the charge between two bodies connected by a conductor, a continuous flow of charge along the conductor would result. The difference in the magnitude of the electrical charge between two bodies is called POTENTIAL DIFFERENCE.

$$V = \frac{w}{q} = \frac{Q}{r}$$

The movement of charge along a conductor; assumed to be the flow of electrons; is called CURRENT.

A convenient method of obtaining a relatively stable potential difference for producing current flow is to immerse two metals of different electrical potential in an electrolyte. This is the principle of the chemical dry and wet cell (battery).

We have learned that the phenomenon of magnetism is considered to be associated with a resultant directional flow of electrons within a conductor. The purpose of this experimental investigation is to learn more about the relationship between magnetism and the directional current flow in conductors.

In the spaces provided following each phase of the study discuss your findings. In each case illustrate your results with a simple diagram neatly drawn, and make a short precise statement summarizing the relationships observed. Establish the directional relationships of electron flow, and magnetic lines of force in all drawings.

PROCEDURES

In this study we shall use dry cell batteries to supply direct current with a potential difference of about 1½ volts. The current flow should be controlled by means of a simple key. Magnetic effects are best observed by closing the circuit momentarily. DO NOT KEEP THE CIRCUIT CLOSED FOR MORE THAN A FEW SECONDS AT A TIME.

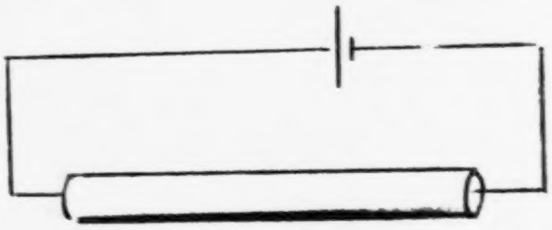
Laboratory Investigation

Name ______________________

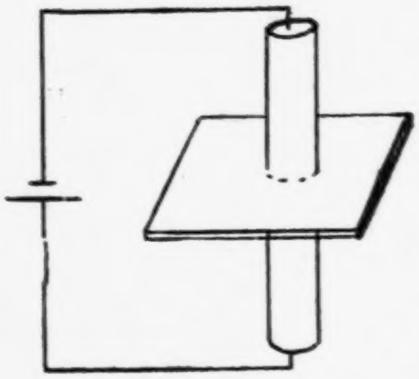
Science IIIA Hour ____

Date ______________________

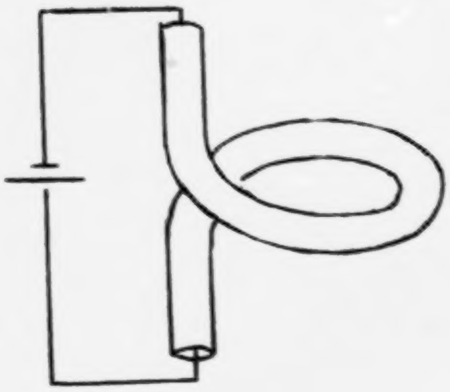
Part I: Describe completely and accurately the nature of the magnetic field which develops about a horizontal conductor carrying current. Be sure to indicate the direction in which the electrons are moving throught the conductor.



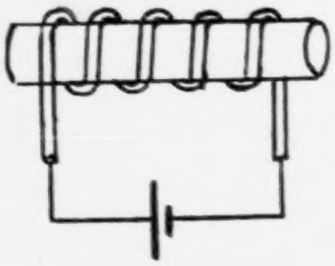
Part II: Describe the nature of the magnetic field set up about a vertical conductor with reference to the direction in which the electrons flow throught the conductor.



Part III: Bend the conductor into a simple circular loop called a "helix". Dicuss the nature of the magnetic field set up about a circular conductor in which current is flowing.

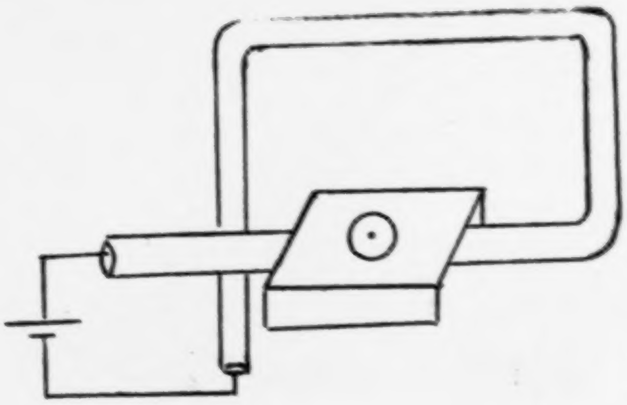


Part IV: Wind the conductor into a tight spiral coil about three inches long. Study the nature of the magnetic field set up about a coiled conductor.



Part V: Prepare a rectangular shaped loop of wire containing a single turn. Position the loop so that its short axis is in a vertical direction and its long axis in a north-south direction. Fold an index card to support a small compass directly over the lower loop of the conductor. Study the effect of current flow on the compass needle.

Determine the effect of an increase in the number of turns, the current flow, (use two batteries in series), and the current flow and number of turns increased simultaneously. Include a neat diagram which indicates the forces acting on the compass needle. Does the principle observed here suggest any practical value?



Interactions Between Electric and Magnetic Fields

ELECTROMAGNETIC INDUCTION

1. The Beginnings of Electromagnetism
    a. Oersted's Discovery - Hans Christian Oersted (1777-1851)

    b. The Direction of Magnetic Fields Set up Around a Conductor

        1) Ampere's Left Hand Rule

        2) The Magnetic Field About or Loop or Solenoid

        3) Bar Magnets and the Polarity of Solenoids

c. Factors that Effect the Intensity of Magnetic Fields Developed Around Conductors

1)

2)

3)

d. Magnetic Hysteresis

2. Induced Currents

a. Faraday's Discovery of "Induction" - Michael Faraday (1791-1867)

b. Joseph Henry - Self Induction and Electromagnetism (1797-1878)

1)

2)

3. The Concept of EMF, Electromotive Force

   a. The Cause of EMF

   b. Factors that Effect Induced EMF

   c. Measurement of EMF

4. Electric Current

   a. Lenz's Law - The Direction of Induced Current
      (H.F. Lenz 1804-1864)

   b. Measurement of Electric Current

      1) Standard Units

77-80

ELECTROMAGNETIC RADIATION

Required Reading: Physics, Physical Science Study Committee, pages 564-576 and 585-633

Electromagnetic Waves

5. Maxwell's Laws
    a. Prediction

6. The Wave Character of the Electromagnetic Spectrum
   a. Electric and Magnetic Components

   b. Common Properties of Electromagnetic Waves
      1. frequency

      2. velocity

      3. wavelength

   c. Observed Phenomona of Electromagnetic Waves
      1. reflection

      2. refraction

      3. interference

      4. diffraction

      5. rectalinear propagation

7. Particle vs. Wave Controversy

The material on page 82 may be found

TITLE Light - Basic Science Series

AUTHOR Alexander Efron

PUBLISHER J. F. Rider Publishing Company

PAGE NO. ?

The material on page 83 may be found

TITLE Physics ~~(Laboratory Guide~~

AUTHOR Physical Science Study Committee

PUBLISHER , D. C. Heath and Company

PAGE NO. 565

84/85

Mechanism of Photoelectric Transduction

8. The Photoelectric Effect

a. The failures of the classical theory in attempting to explain the P. E. effect

86-90

The Quantum Theory

9. The Classical Model (Rutherfords)

10. The Bohr Model of the Atom

The material on pages 90-91 may be found

TITLE	Physics
AUTHOR	Physical Science Study Committee
PUBLISHER	D. C. Heath and Company
PAGE NO.	287

Laboratory Investigation

Name ______________________
Science IV A Hour ____
Date Due ________________

PROBABILITY AND THE WAVE PROPERTIES OF PHOTONS

1. How many different combinations are possible when using a pair of dice?

2. How many different combinations producing the total 7 are possible?

3. How many different combinations producing the total 2 are possible?

4. On the basis of this analysis compute the probability of throwing a 7.
compute the probability of throwing a 2.

5. On the bases of this probability construct a bar graph which will predict the number of 2's and 7's that could be expected in 1000 throws.

6. Throw a pair of dice 100 times. Record the number of times that the total of 2 and 7 came up. From your record for 100 throws compute the fraction:

$$\frac{\text{number of throws totaling 7}}{100} = \underline{\qquad\qquad}$$

$$\frac{\text{number of throws totaling 2}}{100} = \underline{\qquad\qquad}$$

7. How do these percentages compare to those expected in #5?

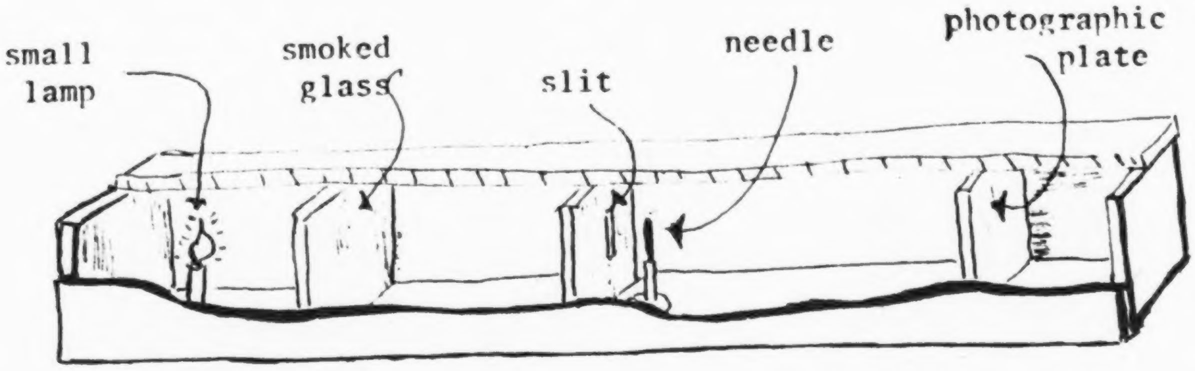
	Expected %	Experimental %
total (2)	_____	_____
total (7)	_____	_____

8. Combine your record with those of ten other groups. Represent these experimental results on your bar graph, along side of the predicted values.

Lab. Continued -

QUESTIONS:

In this experiment to determine whether photons produce interference, G.I. Taylor constructed a light-tight box, At one end of this box he set up a small lamp which cast the shadow of a needle, placed in the middle, onto a photographic plate mounted at the other end.



The positions of the needle and photographic plate were adjusted so that the diffraction bands around the shadow of the needle were plainly visible. The he reduced the intensity of the light source. Longer and longer exposures were required to produce a well defined image on the plate. Finally he reduced the intensity of light to the point where an exposure of three months was required to produce a clear image. Taylor showed that for this level of intensity no more than 1 photon could be present in his box at a time. Yet the diffraction bands produced on the plate were perfectly clear. This shows that interference takes place even for single photons.

1. On the bases of your present knowledge, explain how it is possible that interference and diffraction is possible even though only a few, or no, photons are present at a given moment.

2. A small electric lamp was placed several meters from a photocell. The intensity of the light was reduced by placing a sheet of exposed photographic film in front of the lamp. In a period of one hour, 1800 electron were observed to have been ejected from the surface of the photocell when two sheets of exposed photographic film were placed in front of the lamp it was observed that on the average one electron was ejected from the surface of the photocell every 200 seconds. On the bases of this information what proportion of the photons emitted from the source are absorbed by a sheet of exposed photographic film?

11. The Nature of Photons

a. Physical Properties

b. Probability and Photon Occurance

c. Interference of Photons

d. Absorption of Photons

12. Photon Energy and Wavelength

a. Einstein - Planck Relationship

b. Units of Photon Energy

1) joule

2) electron volt

3) Einstein

c. Momentum

1) Macroparticle

2) Photon

13. The Wave Properties of Particles

a. The Compatibility of Photons and Electromagnetic Waves

1) the radio range

2) visible light

b. de Broglie's Matter Waves

1) direct evidence for the wave properties of particle

2) the effect of particle momentum on wave length (lambda)

3) the wave length of particles

The Material on page 98 may be found

TITLE Physics

AUTHOR Physical Science Study Committee

PUBLISHER D. C. Heath and Company

PAGE NO. 595

3. Calculate the energy, in joules, carried by an "average" photon of visible light having a wave length of 4000 angstroms.

What is the momentum of such a photon?

4. Estimate the number of photons of visible light emitted each second from a 100 watt light bulb. Assume theat 1% of the lamp's power is emitted in the visible region.

5. Light having a wave length of 5000 angstroms illuminates the surface of a metal plate.

   a. If the energy binding electrons to the surface of the metal is 2.0 electron volts/electron, what voltage would be required to prevent the ejection of electrons as a result of the photon absorption?

   b. If one would wait long enough would the accumulation of photons eventually cause electrons to acquire energy in excess of the 2.0 eV and thus be ejected?

Name ____________________

6. A high energy photon having a wave length of one angstrom collides with an electron "at rest". In the resulting collision, the direction of the photon is changed ninty degrees. In such a collision, the fractional loss of energy is very small and the frequency of the photon before and after the collision is practically unchanged. Thus the momentum of the photon before and after collison is:

   a. Calculate the momentum of the photon before collision.

   b. Draw a vector diagram representing the momentum of the photon before and after the collision and the momentum of the electron after the collision. Remember to conserve momentum, the electron must acquire a momentum, p_e, such that the vector sum of p_e and the final momentum of the photon, p_j is equal to the initial momentum of the photon p_j.

   c. Calculate the energy of the photon after the collsion.

   d. Calculate the energy of the electron after the collsion.

7. In the classic three month experiment of G. I. Taylor, proving that interference is a property of individual photons, it is estimated that the energy of the light reaching his photographic plate was 5 x 10^{-13} joules/second.

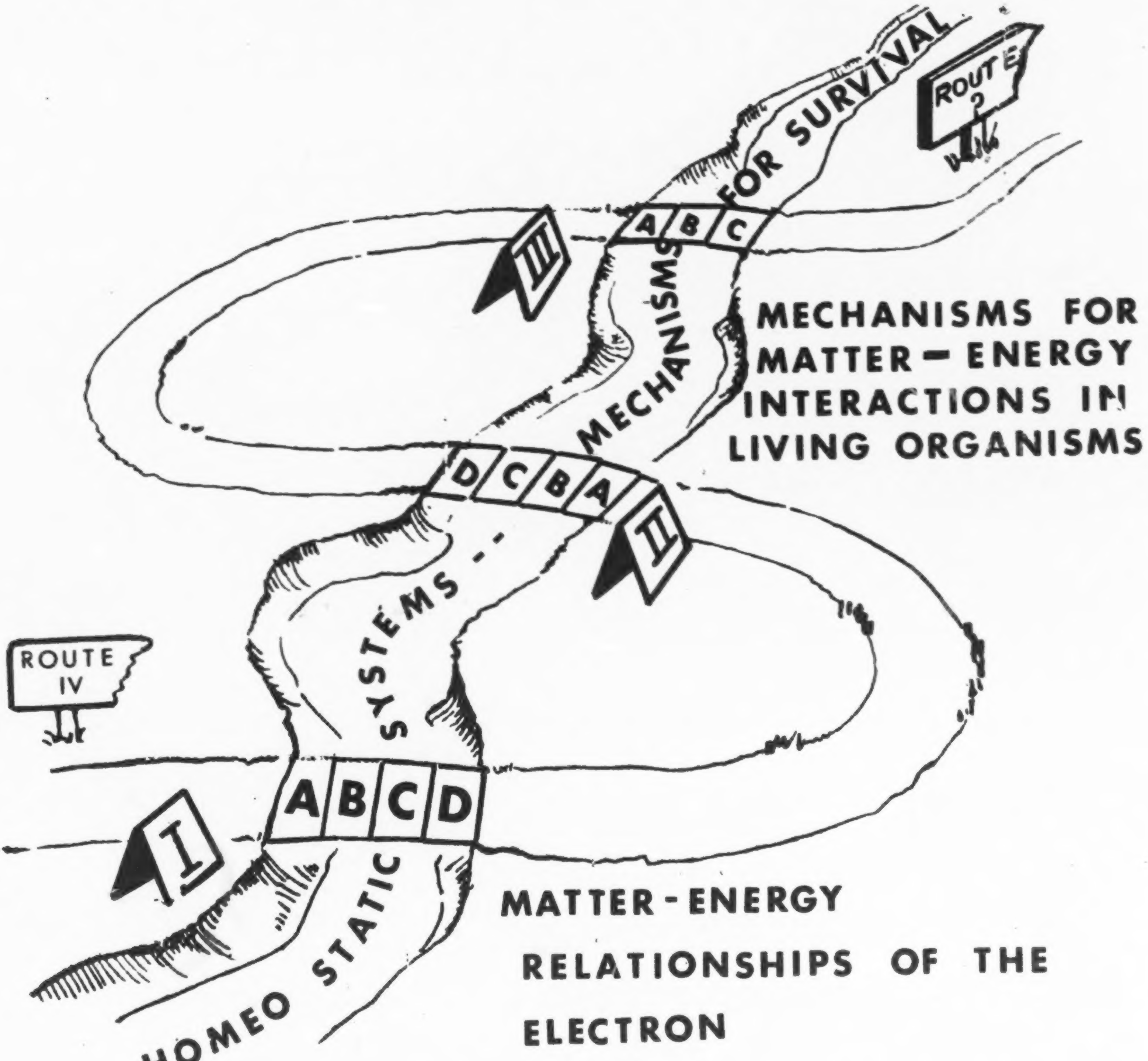
   A. If the wave length of the light reaching the screen was 5000 angstroms, what energy did each photon carry?

   B. On the basis of this flow of energy calculate the average time that elapsed between the arrival of one photon and the next.

   C. On the basis of the average time between photon arrivals, calculate the distance between photons.

   D. If the box used in Taylor's experiment, as described above, was 1.2 meters long, your changes of seeing evidence of a photon's presence in the box, at any given instant would be quite remote. However, if you were to look at the box often enough, eventually you would see one. On the basis of the information given, estimate the odds on your seeing a photon in the box each time you look in it.

SCIENCE IV


ROUTE ?
HOMEOSTATIC SYSTEMS -- MECHANISMS FOR SURVIVAL
I
A B C D
II
D C B A
III
A B C
ROUTE IV
MECHANISMS FOR MATTER – ENERGY INTERACTIONS IN LIVING ORGANISMS
MATTER - ENERGY RELATIONSHIPS OF THE ELECTRON

II. MECHANISMS FOR MATTER-ENERGY INTERACTIONS IN LIVING ORGANISMS

A. Mechanisms Associated with the Capture, Storage and Utilization of Energy and Matter

B. Mechanisms Associated with the Transport, Regulation and Exchange of Matter Throughout the Organism's Internal Environment

C. Mechanisms Associated with the Ability of Organisms to Act and React

D. Mechanisms by which Living Matter Maintains and Propogates its Orderliness Through Space and Time

Mechanisms for the Interaction of Matter and Energy in Living Organisms

MECHANISMS ASSOCIATED WITH THE CAPTURE, STORAGE, AND UTILIZATION OF ENERGY AND MATTER

Photosynthesis

Fermentation and Respiration

Bioluminescence

Vision

Hearing

Mechanisms Associated with the Capture, Storage and Utilization of Energy and Matter

Resource Material

PHOTOSYNTHESIS

Recommended Reading:	Solar Energy Research, Daniels and Duffie
	"Life and Light", George Wald, Scientific American October 1959, #61
	"The Role of Light in Photosynthesis", Daniel I. Arnon, Scientific American, November 1960, #75
	"How Cells Transform Energy", Albert L. Lehninger, Scientific American, September, 1961, #91
	"The Path of Carbon in Photosynthesis", J. A. Bassham, Scientific American, June, 1962, #122
	"The Role of Chlorophyll in Photosynthesis", Eugene I. Rabinewitch and Govindjee, Scientific American, July 1965, #1016
	Photosynthesis, Jerome L. Rosenberg
	"The Acquisition of Light Energy: Photosynthesis", The Biology of Cells, Herbert Stern and David Nanney, pages 279-300

INTRODUCTION:

The energy that supplies all life on the earth comes ultimately from sunlight, through the process of photosynthesis. Each year plants on the earth reduce about 550 billion tons of carbon dioxide, using about 25 billion tons of hydrogen, and releasing about 400 billion tons of oxygen into the atmosphere. About nine-tenths of this activity goes on in the surface layers of the oceans.

No industrial process yet invented converts light economically into useful forms on a large scale. For this reason our economy still depends largely upon the combustion of fossil fuels, themselves the products of photosynthesis in past ages. Under optimal conditions plants can turn light energy to the synthesis of carbohydrate with an over-all efficiency that few workers estimate at less than 50 per cent. We have only recently begun to understand how they accomplish this feat.

For light to be used, it must be absorbed; and substances which absorb visible light are by that token pigments. The pigments which absorb the light used in photosynthesis are found in the chloroplasts of green plants, and in similar particles called chromatophores in photosynthetic bacteria. The principle pigment of chloroplasts is chlorophyll a. Chlorophyll b and the yellow carotenoids play secondary roles, transferring the energy they absorb as light to chlorophyll a for use in photosynthesis. Photosynthetic bacteria possess a special bacteriochlorophyll, and also a number of specific carotenoids.

The net action of light in photosynthesis is to split water, thus providing hydrogen for reductions and eliminating oxygen as a by-product:

$$12\ H_2O \xrightarrow[\text{chloroplasts}]{\text{light}} 24\ H + 6\ O_2$$

The H atoms supplied in this way are used to reduce carbon dioxide, fixed with the aid of ATP, to carbohydrate and water:

$$6\ CO_2 + 24\ H \xrightarrow{18\ ATP} C_6H_{12}O_6 + 6\ H_2O$$

Thus the overall reaction is

$$6\ CO_2 + 12\ H_2O \xrightarrow[\text{chloroplasts}]{\text{light}} C_6H_{12}O_6 + 6\ H_2O + 6\ O_2$$

To fix one molecule of carbon dioxide in the form of carbohydrate thus requires not only 4 H atoms but also 3 "high-energy" phosphate bonds of adenosine triphosphate (ATP). It is now recognized that the energy absorbed as light by chloroplasts generates not only hydrogen, but also ATP. Indeed, isolated chloroplasts can carry out the whole process of photosynthesis.

Carbohydrate, having been prepared by photosynthesis, is in turn degraded to provide all the cell's energetic needs. The two principle processes for giving energy by the degradation of sugars are fermentation and respiration. Fermentation is the process by which cells derive energy without using oxygen, by rearranging the atoms of such an organic molecule as glucose to yield products of lower energy. Respiration is a combustion, in which glucose or other organic molecules (fats, deaminated amino acids) are burned with molecular oxygen to yield carbon dioxide, water, and energy in the form of ATP.

Photosynthesis and respiration are opposed reactions. The overall equation of the former just reverses that of the latter, when glucose is consumed. Green plants respire in the dark; they simultaneously respire and photosynthesize in the light. The consumption of oxygen is a measure of their respiration; the evolution of oxygen measures their photosynthesis. In the light, with both processes going on simultaneously, the oxygen exchange represents a balance between these opposed reactions. If the light is sufficiently bright, however, photosynthesis may be so much faster than respiration as to dominate the oxygen exchange.

TRANSFORMATION OF ELECTROMAGNETIC RADIATION BY PLANTS

I. Nature of the Chloroplast

A. Structure of the Chloroplast

B. Relationship of Structure to Function

II. Structure and Properties of the Chlorophyll Molecules

A. Types

B. Molecular Structure

C. Energy Capture

D. Efficiency of Energy Capture

Laboratory Investigation

PHOTOSYNTHESIS

I. The Pigments of the Chloroplast:

Note: Rinse and lubricate the ground glass joints of the separatory funnel being used with the solvent being used in the particular separation. When the experiment is completed rinse the funnel with alcohol and drain, placing a small slip of paper in each ground glass first.

A. Extraction of the Pigments:

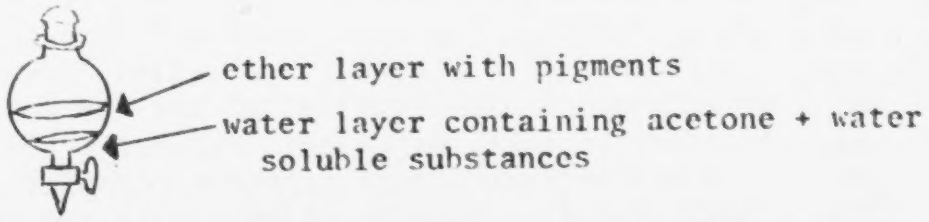
Weigh out 0.5 grams of leaf tissue (discarding large veins). Place the tissue with a very small amount $CaCO_3$ (to neutralize cell acids and prevent the removal of Mg from the chlorophyll nucleus) in a clean mortar and grind to a fine pulp. Add enough 85% acetone to thin the pulp (5-6 ml.). Continue to grind the tissue for several minutes. Allowing the cell debris to settle, tilt the mortar and using an eye dropper, transfer the clear supernatant green liquid to 10 ml. of ethyl ether contained in a 250 ml. separatory funnel. Repeat the above procedure until the plant residue is white - BUT AFTER THE SECOND EXTRACTION ADD ABOUT EQUAL PARTS (3-3 ml) 100% ACETONE AND ETHYL ETHER UNTIL THE LAST EXTRACTION, WHICH SHOULD BE MADE WITH ETHYL ETHER. (This facilitates the extraction of all the pigments-both green and yellow).

SUMMARY OF EXTRACTION PROCEDURE

1. about 2 extractions with acetone (5-6 mls.)
2. about 3 extractions with acetone + ethyl ether (3 ml. each)
3. about 2 extractions with ethyl ether (5-6 mls.)

The green solution in the separatory funnel is a solution of the plastid pigments together with small amounts of other compounds in a mixture of acetone and ethyl ether. The next step is to remove the acetone and any of the extraneous materials that are water soluble. To do this add about 100 ml. of distilled water to the pigment solution in the separatory funnel. ADD THE WATER SLOWLY POURING IT DOWN THE SIDE OF THE SEPRARATORY FUNNEL. ROTATE THE FUNNEL - DO NOT SHAKE - for a few minutes to speed the transfer of the acetone and other substances into the lower water layer.

example


ether layer with pigments
water layer containing acetone + water soluble substances

Fasten the separatory funnel in an upright position. When the two layers are sharply defined, run off the lower layer and discard it. Repeat this washing with distilled water three times following the same procedure as above. (This removes all of the acetone). NOTE: Should the ether layer become very small add about 5 ml. more ether at the time of adding distilled water but do not allow the ether layer to exceed about 15 ml.

When the last distilled water washing is completed - run off the ether solution of the chloroplast pigments into a small graduate. (If necessary, add ether to bring the volume to 10 ml.) Pour the pigment solution into a small bottle containing 2 grams anhydrous Na_2SO_4. Cap the bottle and shake it so the salt is suspended in the liquid - continue the shaking for several minutes. (The anhydrous salt further removes water from the ether.)

B. Separation of the Plastid Pigments:

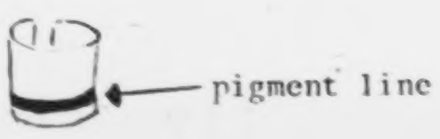
The chloroplast pigments dissolved in ether (from part A) will be separated by the Paper Partition Chromatography method. The principle of the method is as follows: When a solution consisting of a single solute dissolved in a pure solvent is brought into contact with a second solvent which does not mix with the first solvent, the solute will tend to become distributed between the two solvents in a definite ratio, depending upon its relative solubility in the two solvents. Therefore if a solute is dissolved in a mixture of two solvents, the difference in the affinity of the solute for the two solvents can be revealed by using some inert substance (filter paper) through which the solvents move a different rates. The solute will follow the most rapidly moving solvent rapidly or slowly according to its relative affinity for this solvent. If several solutes are contained in the solvent mixture (as they are here, since there are several chlorophylls in the ether) and if these have different affinities for the two solvents, there will be a separation of the solutes during the movement of the solvents along the strip of filter paper.

Obtain the following materials:

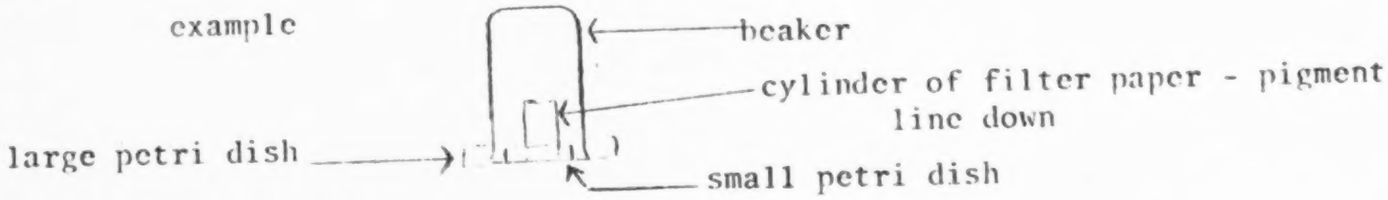
500 ml beaker
one half of petri dish large enought to cover beaker
one half of small petri dish
eye dropper, preferably with a fine tip
3 10 x 80 mm. corked test tubes
135 mm. square of #1 filter paper

Note: (Wash and dry hands before handling filter paper and handle this paper only between folds of paper - to prevent grease spotting or smudging.) Mark the filter paper with a lightly pencilled line parallel to and at a distance of ½ inch from one side. While holding the filter paper so that the marked edge does not contact any object, deliver a fraction of a milliliter of the plastid solution from a fine tipped eyedropper along the line on the paper. The pigment solution must be added slowly and evenly along the line since the object is to build up two pigment fronts - parallel with the pencil line and separated by a distance of one-half an inch. When the ether has evaporated from the paper, add another small portion of the ether solution. Continue to build up the pigment fronts on the strip until all of the pigment solution has been added. After allowing several minutes for the paper to become free of ether by evaporation, cut the paper strip along the pencilled line and discard the short piece. Form the piece of filter paper into a cylinder, pigment line outward and at one end, and staple each end.

example



Place the half of the smaller petri dish in the larger. Add about 5 ml. of a 9:1 mixture of petroleum ether and benzene to the smaller petri dish. Use enough of this solvent to provide a liquid layer whose depth is equal to ½ the distance between the pigment line and the bottom of the filter paper cylinder. Immediately place the paper cylinder, pigment line down, into the solvent mixture, and invert the beaker over the cylinder and inner dish.



Allow the set up to remain undisturbed until an orange band (this is a mixture of yellow carotine pigments) has advanced about 5 cm. beyond the pigments below. When this stage is reached, remove the filter paper cylinder and replace the solvent mixture with an equal amount of 4:1 mixture of petroleum ether and benzene. Reinsert the filter paper cylinder and cover the whole with the beaker as before. Allow to develop further until it is possible to identify;

1. the blue green chlorophyll a
2. the pure green chlorophyll b
3. the yellow xanthophyll (several yellow pigments)

When the four pigments have separated into distinct bands remove the filter paper and allow the solvents to evaporate.

I. When the chromatogram is dry, examine the pigments as they appear on the paper.

   1. Assign an identification number to each spot or band of pitment you observe. Outline the spots (or bands) lightly in pencil. Do not use ball point or ink; it will interfere with your results for Parts II and III.

   2. Measure the diameter or width of each spot in millimeters. Also determine the R_f value, which is the ratio of the distance travelled by the pigment from its origin on the paper - to the distance travelled by the solvent-front from the same origin.

   3. Record the color of each spot as it appears in white light.

   4. Examine the chromatogram under ultra violet light noting the properties of each pigment. Is the U.V. light reflected or absorbed by the pigment? Does the pigment fluoresce? Are any additional spots or bands apparent that were not so in white light? If so, record their properties on the data sheet.

II. With a scissors, cut out the pigment bands from your chromatogram and pool them with those of other class members. Be sure to keep each kind of pigment separate. Elute the pieces of paper by soaking in a few millimeters of acetone in small test tubes, using a separate test tube for each pigment. Leave the pieces of paper in long enough to clearly color the acetone.

Examine the diluted samples, recording their color in white light and noting the quality of light reflected, transmitted, absorbed, or fluoresced. To study fluorescence, observe the sample at right angles to a narrow beam of white light while in a dark room.

Examine properties of each sample when exposed to U.V. light, noting whether or not it is reflected, absorbed, or fluoresced.

III. Using the spectrophotometer (see appendix for operation) obtain absorbance (optical density) readings over a range of wavelengths from 380 to 700 mμ for each of the eluted samples. Use 20 mμ intervals, except in regions of maximum or minimum absorption where readings should be taken closer together (5, 10 or 15 mμ). Readings on the chlorophylls should run from about 400 - 700 mμ, whereas those for caroenoid pigments should run from about 400 to 600 mμ. Be sure to switch to the red-sensitive phototube and filter when readings are being taken above 650 mμ. Record data for each pitment in section III of the data sheet.

DATA SHEET

Name ______________________________

Science IV A Hour _____

Date ______________________________

I. Properties of Photosynthetic Pigments on Paper

Spot #	R_f Value	Diameter or Width of Spot in mm	Color in White Light	Color in U.V. Light Reflected Absorbed Fluoresced

II. Properties of Eluted Photosynthetic Pigments

Sample # (same as Spot #)	Color in White Light				Color in U.V. Light		
	Reflected	Transmitted	Absorbed	Fluoresced	Reflected	Absorbed	Fluoresced

111

III. Absorption Data

λ mμ	Chlorophyll a	Chlorophyll b	Xanthophyll	Carotene
380				
385				
390				
395				
400				
405				
410				
415				
420				
425				
430				
435				
440				
460				
480				
500				
520				
540				
560				
580				
600				
620				
640				
650				
655				
660				
665				
670				
675				
680				

QUESTIONS

Name ______________________

Science IV A Hour _____

Date ______________________

1. What is the difference in the molecular structures of chlorophylls a and b?

2. What are the molecular structures of carotene and xanthophyll?

3. How do you account for the appearance of fall colors in the trees?

4. On graph paper, plot the absorption curve (absorbance against wavelength) for each pigment.

   a. Identify maximal absorption peaks for each pigment.

   b. How would the narrowness or braodness of the peaks obtained for an isolated pigment relate to its purity?
   Hint: How would the presence of impurities (other pigments) affect the widths of these peaks?

   c. How do the plotted curves compare to that for the "action spectrum" for photosynthesis? What does this suggest? (The action spectrum was obtained by permitting various wavelength of monochromatic light to fall on a green plant, then the photosynthetic rate was measured at each wavelength and the values plotted (photosynthetic rate against wavelength).

   d. How could absorption curves, such as the ones you have just plotted, be used to identify a number of different light-sensitive pigments?

5. Taking the wavelength that corresponds to the color of light that was fluoresced by chlorophyll a, calculate the number of gram-calories per mole of photons that the energy of this wavelength is equivalent to. Compare the value to that for the light that was absorbed by chlorophyll a. Does this suggest 100% efficiency in the capture and utilization of light for photosynthesis?

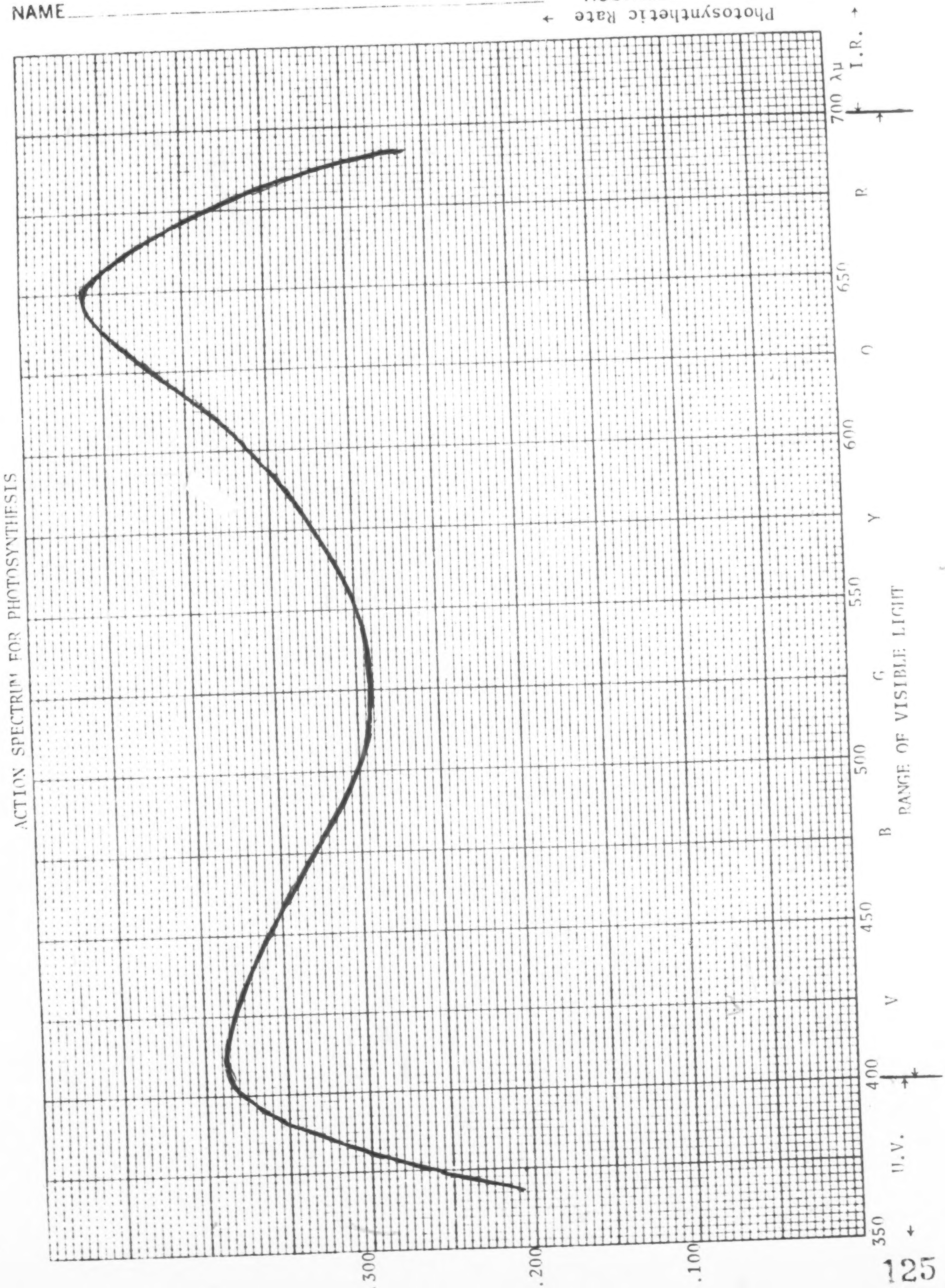
6. Suppose that red light of 6700 Å is absorbed by chlorophyll.

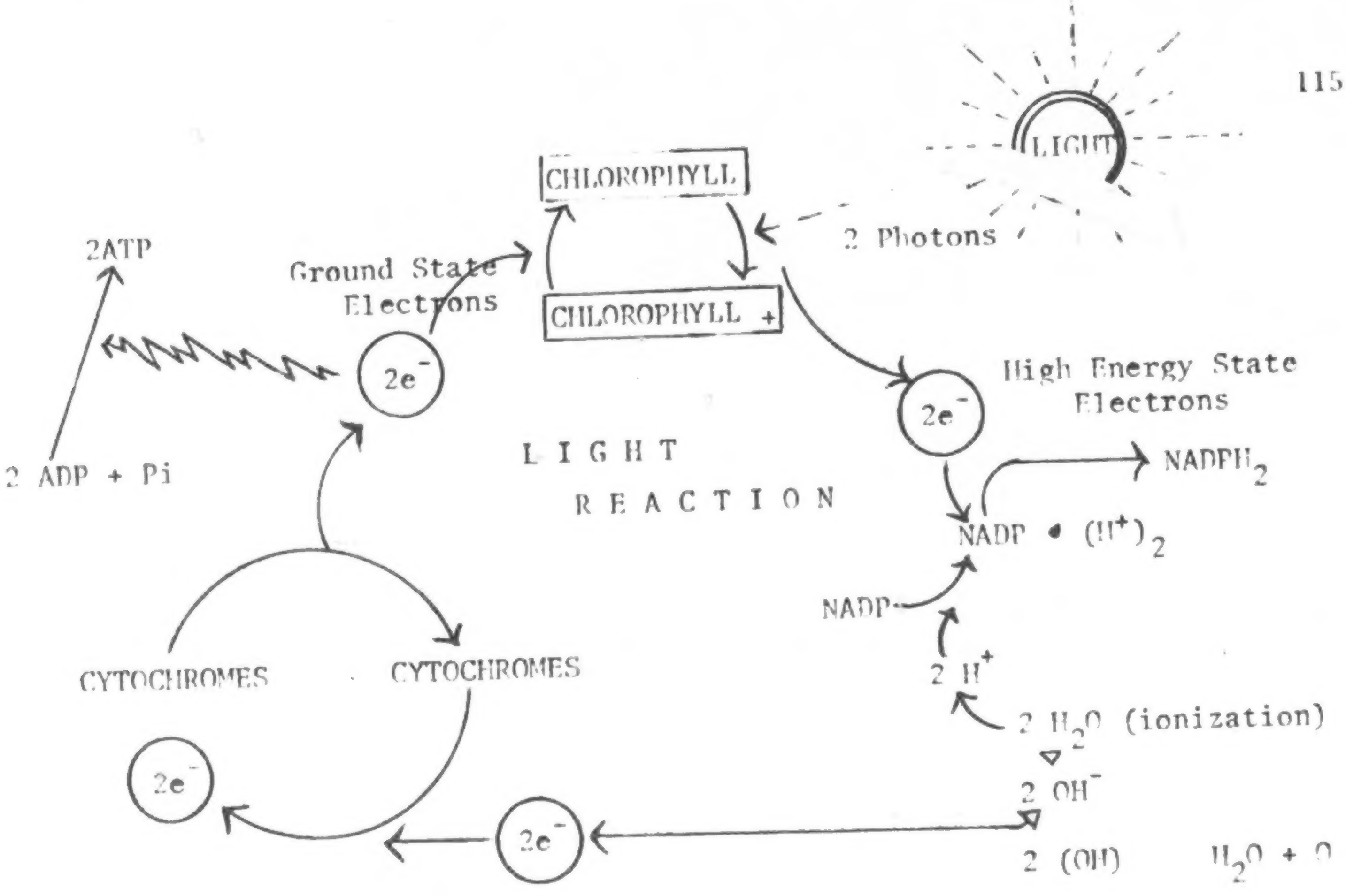
   a. Show that the frequency of this light is 4.5×10^{14} cps.

   b. How much energy is absorbed per mole of photons absorbed?

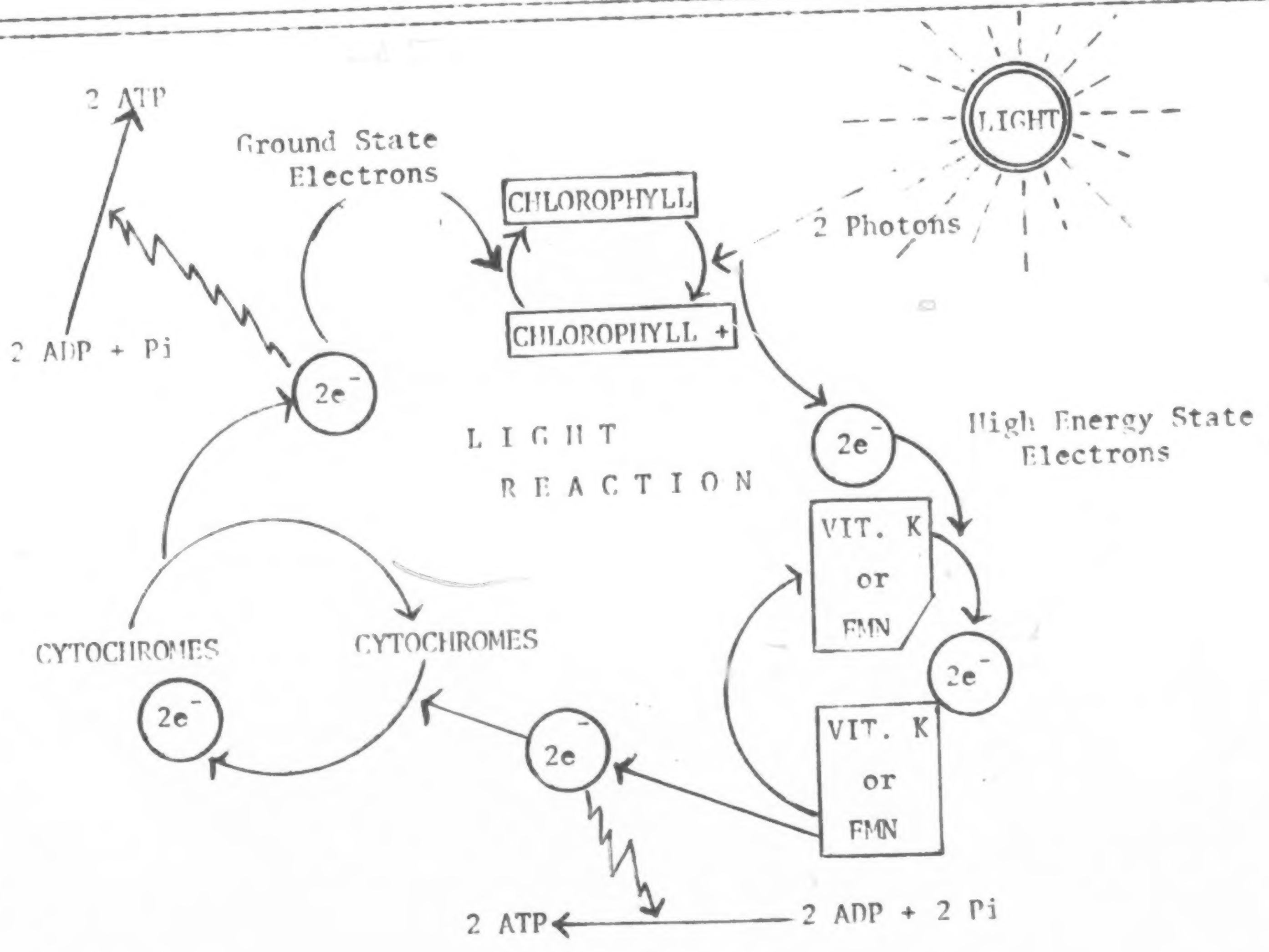
   c. How many moles of photons would be needed to provide enough energy to produce one mole of glucose by the net photosynthetic reaction if all of the energy were provided by red light alone?

NAME________________________________ HOUR______________


ACTION SPECTRUM FOR PHOTOSYNTHESIS

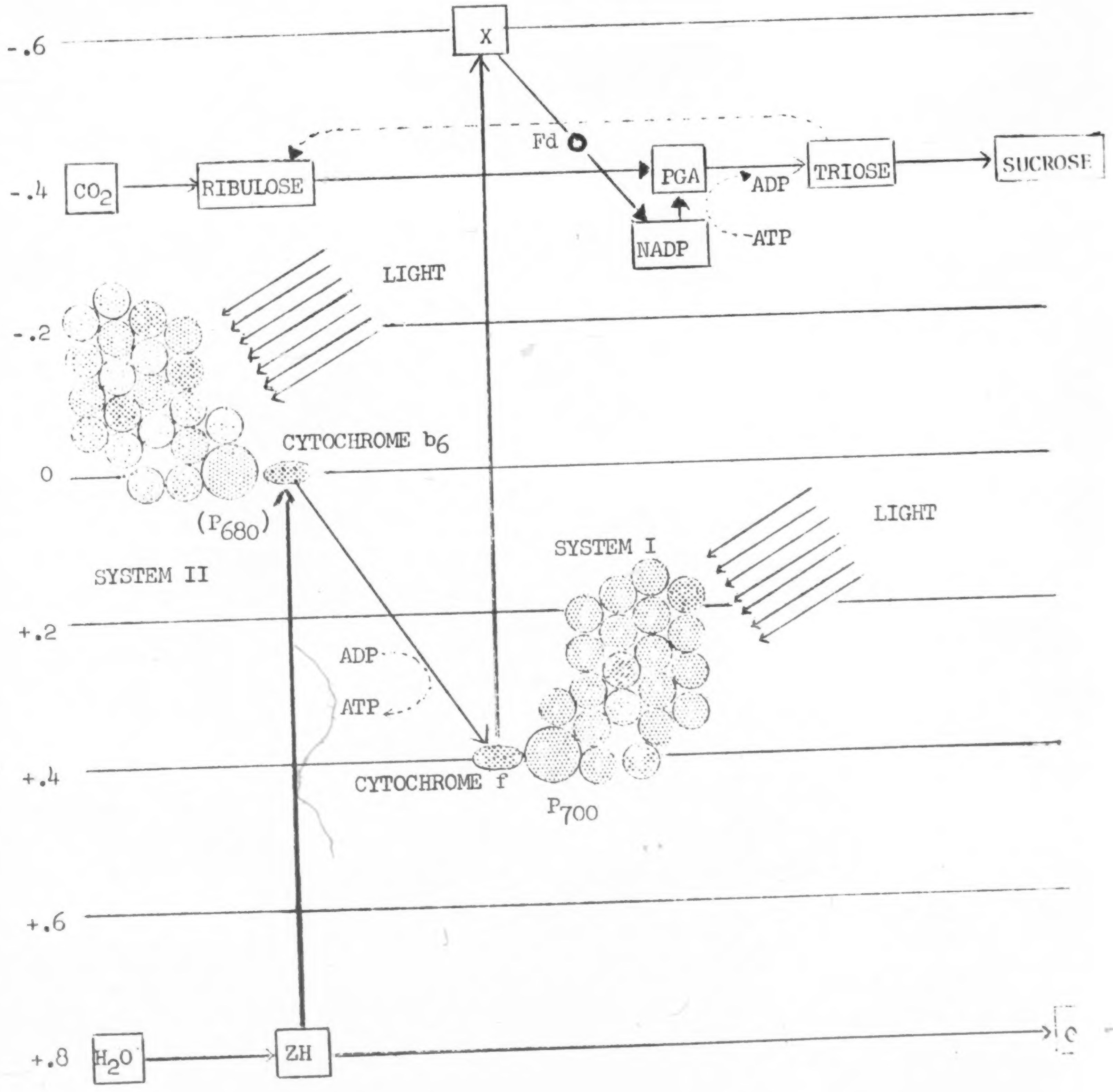

LIGHT
2 Photons
CHLOROPHYLL
CHLOROPHYLL +
2ATP
Ground State Electrons
2e⁻
2 ADP + Pi
LIGHT REACTION
High Energy State Electrons
2e⁻
NADPH2
NADP • (H⁺)2
NADP
2 H⁺
2 H2O (ionization)
2 OH⁻
2 (OH) H2O + O
CYTOCHROMES
CYTOCHROMES
2e⁻
2e⁻

NON-CYCLIC ENERGY TRANSFER (photophosphorylation)

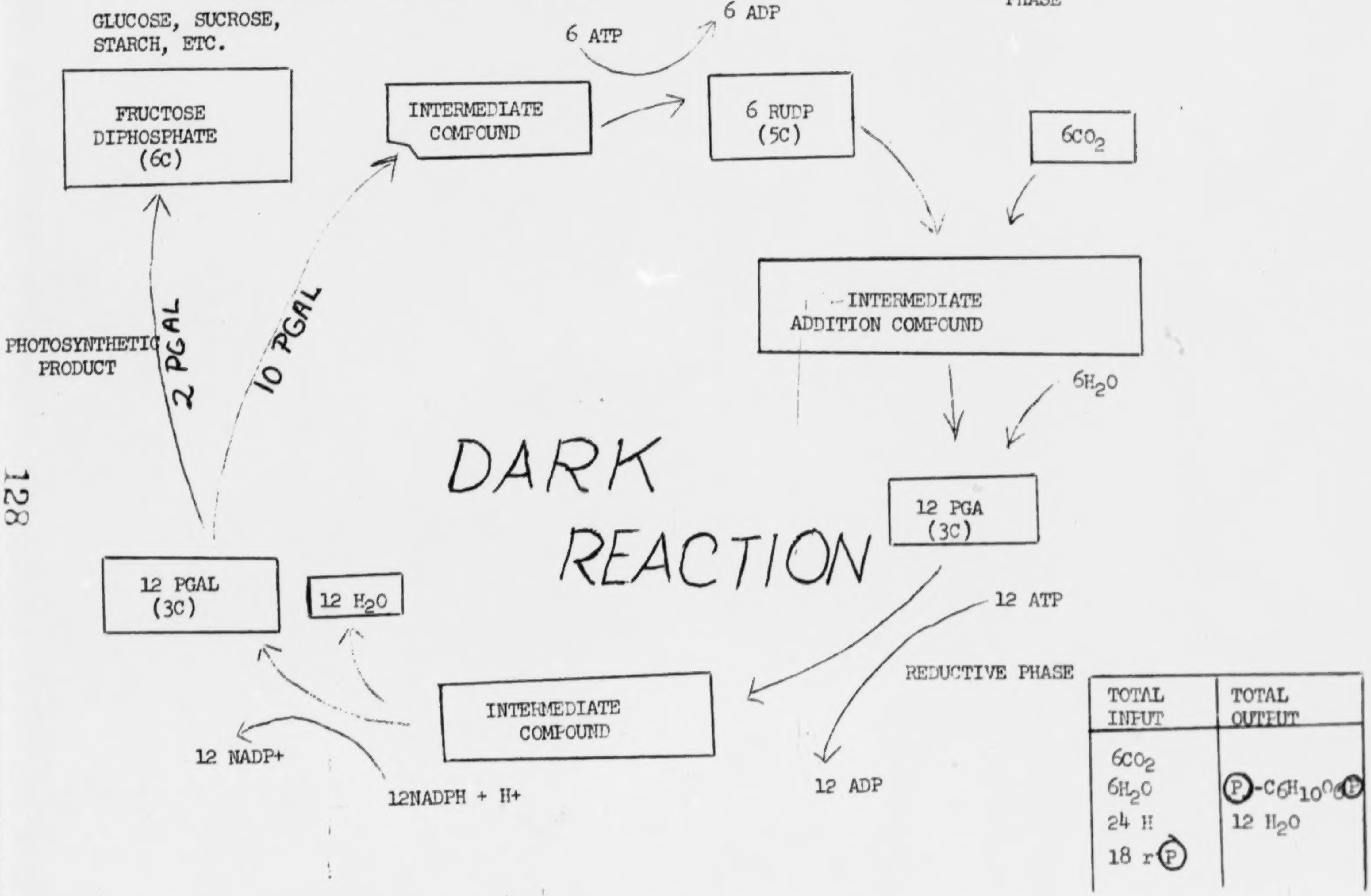

2 ATP
Ground State Electrons
LIGHT
2 Photons
CHLOROPHYLL
CHLOROPHYLL +
2 ADP + Pi
2e⁻
LIGHT REACTION
High Energy State Electrons
2e⁻
VIT. K or FMN
2e⁻
VIT. K or FMN
CYTOCHROMES
CYTOCHROMES
2e⁻
2e⁻
2 ATP
2 ADP + 2 Pi

CYCLIC ENERGY TRANSFER (photophosphorylation)

ENERGY TRANSFER INVOLVED IN PHOTOPHOSPHORYLATION


-.6
X
Fd
CO$_2$
RIBULOSE
PGA
ADP
TRIOSE
SUCROSE
-.4
NADP
ATP
LIGHT
-.2
CYTOCHROME b$_6$
0
(P$_{680}$)
SYSTEM II
LIGHT
SYSTEM I
+.2
ADP
ATP
+.4
CYTOCHROME f
P$_{700}$
+.6
+.8
H$_2$O
ZH

DARK REACTION - THE REDUCTION OF CO_2 BY HYDROGEN
(ATP source from light reaction)


CAROBOXYLATIVE PHASE
GLUCOSE, SUCROSE, STARCH, ETC.
FRUCTOSE DIPHOSPHATE (6C)
6 ATP
6 ADP
INTERMEDIATE COMPOUND
6 RUDP (5C)
6CO2
INTERMEDIATE ADDITION COMPOUND
6H2O
PHOTOSYNTHETIC PRODUCT
2 PGAL
10 PGAL
DARK REACTION
12 PGA (3C)
12 PGAL (3C)
12 H2O
12 ATP
REDUCTIVE PHASE
INTERMEDIATE COMPOUND
12 NADP+
12NADPH + H+
12 ADP

TOTAL INPUT	TOTAL OUTPUT
$6CO_2$ $6H_2O$ 24 H 18 rⓅ	Ⓟ-$C_6H_{10}O_6$Ⓟ 12 H_2O

UTILIZATION OF TRANSFORMED ENERGY WITHIN THE PLANT

I. Photosynthesis - Total Reaction

  A. Methods of Investigation

  B. General Equation

  C. Factors Affecting Reaction Rate

II. Photosynthesis - Light Reaction

  A. General Equation

  B. Oxidation and Reduction Reactions

  C. ATP and Energy Rich Bonds

  D. Detailed View of the Light Reaction (see page 106)

Laboratory Investigation

CARBON DIOXIDE AND PHOTOSYNTHESIS

INTRODUCTION:

Carbon dioxide is one of the materials necessary for photosynthesis. The rate at which a green plant absorbs carbon dioxide is an indicator of the rate of photosynthesis.

In this investigation, you will utilize a chemical indicator to determine the conditions under which a plant absorbs carbon dioxide.

MATERIALS:

- Anacharis
- 250 ml. beakers
- test tubes
- test tube rack
- Bunsen burner
- drinking straws
- limewater
- dilute HCl
- $NaOH$ in dropping bottle
- bromthymol blue solution
- 250 watt bulb
- reflector hood

PURPOSE:

To demonstrate that a green plant absorbs carbon dioxide in the presence of light.

PROCEDURE:

A. On your table you will find one beaker half full of clear limewater and another beaker half full of bromthymol blue solution. Pour about one inch of bromthymol blue solution into a test tube. Pour an equal volume of limewater into a second test tube.

Exhale through a drinking straw into the bromthymol blue for several minutes until you notice a color change. Do the same for the test tube containing limewater. The reaction may be summarized in the following chemical equations:

$$H_2O + CO_2 \rightarrow H_2CO_3 \text{ (carbonic acid)}$$

$$Ca(OH)_2 \text{ (limewater)} + H_2CO_3 \rightarrow 2\ H_2O + CaCO_3 \text{ (white precipitate)}$$

The pH range of bromthymol blue is between 6.0 and 7.6. At 7.6 it is blue and turns yellow as it approaches 6.0.

The reaction with bromthymol blue may be summarized in the following equation:

$$CO_2 + H_2O \rightarrow H_2CO_3$$

$$\text{bromthymol blue} + H_2CO_3 \rightarrow \text{bromthymol yellow}$$

1. Why is the limewater commonly used as a test for carbon dioxide?

2. Explain why air exhaled into bromthymol blue causes a change in color.

B. Divide the bromthymol yellow into two test tubes. Using a test tube holder, gently heat one tube over a flame until a color change is noted. To the remaining bromthymol blue in the second test tube, add a weak base, such as NaOH from a dropping bottle. After each drop, shake the contents of the test tube to ensure its mixture.

3. Explain the reaction on the basis of the pH chart.

C. Your teacher will add some hydrochloric acid to bromthymol blue and then heat it.

4. Compare the effect of heating in this case with heating bromthymol blue that has turned yellow because of the addition of CO_2.

D. Blow into a test tube of bromthymol blue until the solution turns yellow. As soon as you note the yellow color, stop. Place an aquatic plant, we will use Anacharis, in the test tube of bromthymol yellow. Based on your study of photosynthesis, set up additional test tubes in a controlled experiment to test the hypothesis as stated in the purpose of this investigation.

Place your test tube setups in front of 250 watt bulb in a reflector hood. In place of such a light source, the test tube rack may be set up on a sunny windowsill. With good illumination, a reaction may be noticed in 45 minutes.

Periodically observe the test tubes and note any changes that occur.

5. Record your observations.

REVIEW QUESTIONS;

1. Describe the procedure you followed in your experiment with the aquatic plant.

2. Describe why a reaction occurred with the bromthymol yellow and an aquatic plant in the presence of light.

3. Criticize your experimental setup. Suggest possible improvements in your experiment.

4. Summarize the results of your investigation. Be sure to include a discussion of your controls and the specific function of each control you employed.

Laboratory Investigation

THE HILL REACTION

The photolytic cleavage of water in the presence of chloroplasts is known as the Hill reaction. It can be represented by the following equation:

$$A + H_2O \xrightarrow[\text{chloroplasts}]{\text{light}} H_2A + \tfrac{1}{2} O_2$$

In this reaction"A" represents an electron- (or hydrogen-) acceptor. In plants this is usually the coenzyme TPN. In our experiment we shall use an artificial acceptor, the dye 2, 6-dichlorophenolindophenol, which is reduced with the concomitant evolution of oxygen. You will be able to follow the course of the reaction by observing the loss of blue color as the dye is reduced:

$$\text{dye(blue)} + H_2O \xrightarrow[\text{chloroplasts}]{\text{light}} \text{dye} - H_2\text{(colorless)} + \tfrac{1}{2} O_2$$

Prepare spinach chloroplasts as follows: Homogenize with 0.5M sucrose solution at 0°C for 30 seconds in a Waring blendor. Filter the suspension through two layers of cheese cloth. The filtrate should then be centrifuged at 50 times the force of gravity (50G) for 10 minutes. The supernatant is then decanted and discarded. The pellet at the bottom, containing the chloroplasts, should be resuspended in 0.5M sucrose. It is important to keep the chloroplasts at 0°C; they deteriorate rapidly at higher temperatures.

In each of two test tubes, mix:

2 ml. of phosphate buffer, 0.1M, pH 6.5
2 ml. of dye solution (2, 6 dichlorophenolindophenol, 2.5×10^{-4}M)
0.1 ml. of chloroplasts suspension (2 drops)
6 ml. of distilled water

Swirl to mix, wrap one tube immediately in aluminum foil to protect it from light, and expose the other to bright light for 10 minutes. Compare. (Protect the chloroplasts from heat radiation by placing a glass tumbler filled with water between the light source and the reaction tubes.)

Devise an experiment to show that the chloroplasts and dye must be illuminated together to obtain this result. Describe it in your notes. What does this mean for the plant?

EXERCISE - Questions Based on Outside Readings

Name ______________________

Science IV

Date ______________________

1. What are the major chemical events occurring in the dark reactions of photosynthesis? How do these depend upon the results of the light reaction?

2. What is the source of the oxygen gas given off by a photosynthesizing plant? What was the classical experiment which demonstrated this?

3. Carbon dioxide diffuses into the leaf very readily in sunshine. Describe how this diffusion occurs.

4. What wavelengths of light are transmitted by the chloroplasts? How could this be demonstrated experimentally?

5. What information does the equation $CO_2 + H_2O \longrightarrow (CH_2O)_n + O_2$ contain? What information does it omit?

6. What makes the chlorophylls unique as a group of chemical substances?

7. What is an "electron donor"?

8. What technique did Calvin use to separate the many chemicals that are a part of photosynthesis and also identify the location of the C^{14}?

9. What makes photosynthesis different from other means of synthesizing carbohydrates?

10. How do we know that the oxygen from photosynthesis comes from water?

CALORIC CONTENT OF CARBON COMPOUNDS

I. Review of Carbon Compounds

A. Their Origin

B. Kinds of Carbon Compounds

1. Carbohydrates

2. Proteins

3. Lipids

C. Carbon Compounds as Foods

FOOD SUBSTANCES

Substance	Kind of Substance	Essential For	Source
water	inorganic compd.	composition of protoplasm and blood	all foods (released during oxidation)
sodium compd.	mineral salts	blood and other body tissues	table salt, vegetables
calcium compd.	mineral salts	deposition in bones and teeth	milk, whole-grain cereals, vegetables, meats
phosphorus compounds	mineral salts	deposition in bones and teeth	milk, whole-grain cereals, vegetables, meats
magnesium	mineral salts	muscle and nerve action	vegetables
potassium compounds	mineral salts	blood and cell activities	vegetables
iron compd.	mineral salts	formation of red blood corpuscles	leafy vegetables, liver, meats, raisins, prunes
iodine	mineral salts	secretion by thyroid gland	sea foods, water, iodized salt
carbohydrates	organic nutrients	energy (stored as fat or glycogen), bulk in diet	cereals, bread, pastries, tapioca, fruits, vegetables
fats	organic nutrients	energy (stored as fat or glycogen)	butter, cream, cheese, oleomargarine, lard, oils, nuts, meats
proteins	organic nutrients	growth, maintenance, and repair of protoplasm	lean meats, eggs, milk, wheat, beans, peas, cheese
vitamins	complex organic substances	regulation of body processes, prevention of deficiency diseases	various foods, especially milk, butter, lean meats, fruits, leafy vegetables, also made synthetically

2. Caloric Content of Carbon Compounds

a. The Calorie - A Definition

b. The Calorimeter - Measuring Stored Energy

Fermentation and Respiration

PATHWAYS OF ENERGY TRANSFORMATION IN LIVING CELLS

Required Reading:	BSCS Yellow Version, pages 226-229 BSCS Blue Version, pages 199-203 Scientific American Offprint #69, "Energy Transformation in the Cell" Scientific American Offprint #36, "Powerhouse of the Cell"
Major Concepts:	Respiration is essentially the reverse of the photosynthetic process Respiration is a more efficient process than fermentation.

I. Anaerobic Respiration

- A. Fermentation
  - 1. Definition
  - 2. History
    - a. Pasteur
    - b. Lavoisier
    - c. Buchner
  - 3. Examples

4. Relationship of Enzymes

5. Fermentation as a Source of Energy

6. Outline of Fermentation Reaction

Laboratory Investigations

FERMENTATION

Release of Energy

INTRODUCTION:

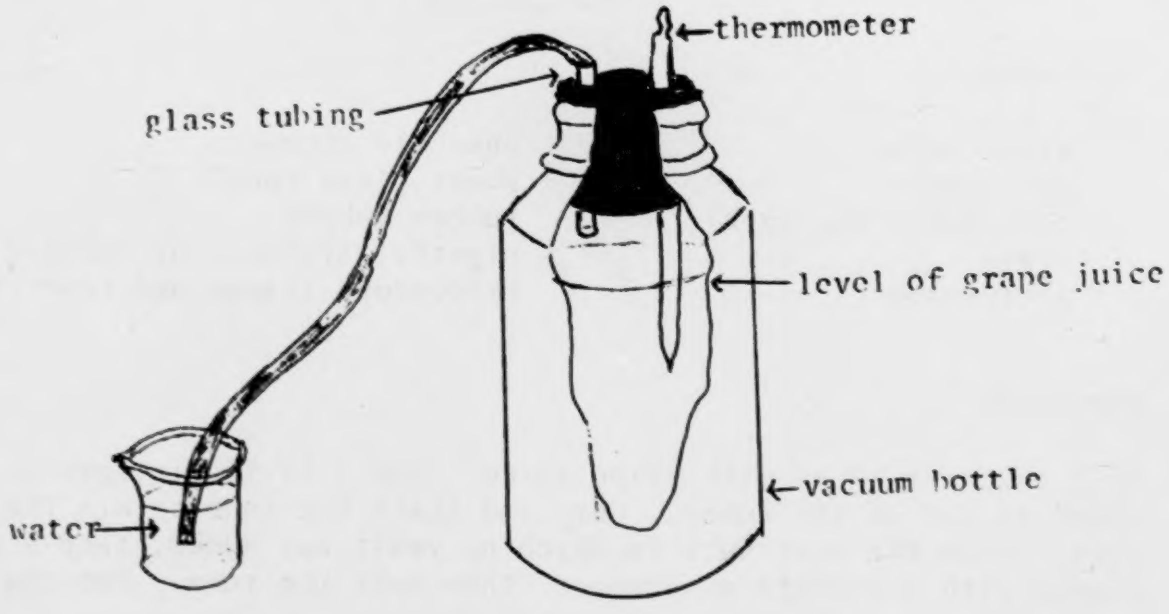
How can you devise an experiment that will clearly show the energy release that occurs during fermentation? What factors might be considered evidence of energy release in such an experiment? One of the most clear-cut indications of energy release is heat. Heat is also easy to measure. In fact, as you shall see for yourself, temperature measurements are an excellent way of detecting energy release during fermentation.

MATERIALS:

- 2 vacuum bottles
- 2 two-hole stoppers to fit vacuum bottles
- 2 short pieces of glass tubing
- 2 beakers or other containers
- 2 thermometers
- rubber tubing
- grape juice
- dry yeast

PROCEDURE:

Set up the apparatus as shown below. Insert a short glass tube through one of the holes of each of 2 two-hole stoppers. Carefully insert a thermometer through the other hole. CAUTION: Before inserting glass tubing in a stopper, always wet the outside of the tube. This will make the insertion easier.



Pour grape juice into both vacuum bottles until they are nearly full. To one bottle add about ¼ package (2 g) of dry yeast. Do not add yeast to the other vacuum bottle. It is to be used as a control. Place the stoppers in the vacuum bottles so that the thermometers, but not the glass tube, dip into the liquid. Attach the piece of rubber tubing to each glass tube and place the opposite end of the rubber tubing under water in a beaker or other container.

Label the two vacuum bottles so there is no doubt which is which. Prepare a table and record the temperature of both the experimental and control bottles as frequently as possible for the next 48 hours. Prepare a graph showing time on the horizontal axis and the temperature in the bottles on the vertical axis. Use solid circles for one set of points and open circles for the other, or use different colors.

QUESTIONS:

1. What evidence is there that a reaction is occurring? How could you prove that this reaction is fermentation?
2. What evidence is there that energy is being released?
3. Interpret the graph that you have prepared.
4. It may be necessary to suspend temperature readings during certain intervals, such as overnight. What effect does this have on the graph?
5. Might it be possible to devise an electrical system which would keep a continuous record of temperature during the experiment?

Growth of Yeast

MATERIALS:

- grape juice
- dry yeast
- test tubes and rack
- corks
- microscope
- one-hole stoppers
- short glass tubes
- rubber tubing
- pipette, syringe, or dropper
- microscope slides and cover slips

PROCEDURE:

Fill two test tubes with grape juice. Add 5 to 10 tiny grains of dry yeast to one of the tubes. Cork and shake the tube to mix the yeast well. From the test tube to which no yeast was added, take a drop of liquid with a pipette or dropper, then cork the tube. Put the drop on a microscope slide, cover with a cover slip, and observe under the high power of the microscope. For comparison, examine a drop of the grape juice to which yeast was added. Observe the yeast cells under the high power of the microscope. Make a rough estimate of the number of cells present in the high power field. Make sketches to show the general appearance of the cells.

Obtain 2 one-hole stoppers. Through each hole insert a short piece of glass tubing to which is attached a piece of rubber tubing. Pour a few centimeters of water into each of two clean test tubes. Set the tubes in the rack.

Insert the one-hole stoppers in place of the corks on the test tubes of grape juice. Set the tubes in the rack, inserting the end of each piece of rubber tubing beneath the water surface in one of the test tubes of water. Observe and describe the visible results in the two test tubes of grape juice for the next two days.

On the second day after starting the experiment, place a drop from the tube that contains yeast on a slide. Examine the sample with the microscope and roughly estimate the number of yeast cells as compared with the number present at the beginning of the experiment. Describe and sketch any difference in the appearance of the cells.

QUESTIONS:

6. What evidence is there that fermentation has been occurring?

7. How does the appearance of the yeast cells change during the experiment?

8. Does this change support the hypothesis that fermentation is an energy-releasing process? What two assumptions are necessary before you can draw this conclusion?

"Wild" Yeasts and Other Organisms

MATERIALS:

- fresh grapes
- test tubes
- aluminum foil
- droppers
- cotton swabs
- petri dishes of grape juice agar
- dissecting microscope (optional)
- compound microscope
- slides and cover slips
- labels or wax pencils

PROCEDURE:

From a bunch of fresh grapes, select a firm grape with a waxy, whitish "bloom" on the skin. Rub the grape against a paper towel to remove as much of the bloom as possible. Open a petri dish of agar and roll the polished grape over the surface. Press very gently, so that the jellylike agar surface is not broken. After most of the surface of the grape has come into contact with the agar surface, discard the grape and replace the cover.

Take a second petri dish of grape-juice agar and remove the cover. Over the surface of the agar, roll a fresh grape from which the bloom has not been removed. Discard the grape and cover the dish. Label both petri dishes and set them in a moderately cool place.

Crush a few grapes in a beaker or other container. Pour the crushed grapes (skins, pulp, seeds, juice, and all) into a test tube until it is about 3/4 full. Cover the test tube loosely with a piece of aluminum foil and set it in a moderately cool place.

Observe the petri dishes and the test tube of crushed grapes for two or three days. Look for evidence of fermentation in the test tube. Examine the surface of the agar for colonies of microorganisms.

If there is fermentation in the tube of crushed grapes, you can learn whether yeasts or other microorganisms are present by "plating" on petri dishes of agar. With a long dropper, remove a drop of the fermenting juice from near the bottom of the test tube. Place the drop in a test tube with 10 ml. of distilled water. (This technique is used so that the colonies that form will not be too close together for convenient observation.) Dip a cotton swab in the diluted juice and "paint" over the surface of a fresh agar plate. Allow 2-3 days for colonies to develop. If you wish, compare with the results obtained when the drop of fermenting juice is taken from near the top of the test tube.

Study all the petri dishes with a dissecting microscope if one is available. Mount samples of the colonies and study the organisms with a compound microscope.

QUESTIONS:

9. According to your observations, what general kinds of organisms occur on grape skins?

10. How can you be sure that any organisms that form colonies on your petri dishes of agar did not come from the air or from your fingers?

11. Would all the organisms that might be present on grape skins grow equally well on the same medium and at the same temperature? How could you find out?

12. What evidence is there that fermentation of bottled grape juice by bread yeast is the same kind of chemical process as the fermentation of crushed fresh grapes by wild yeasts?

Additional Investigations

The additional investigations in the following list are presented as questions to be answered by experiment. You probably have other questions to add to these. In nearly all the problems suggested, the necessary materials would not be hard to obtain.

A. Grape juice and apple juice sometimes turn to vinegar. Under what conditions is this change most likely to occur? What kinds of organisms, if any, are responsible for the change? How is the change similar to and how is it different from fermentation by yeast?

B. Buttermilk, sour cream, and yoghurt are all flavored by the action of microorganisms. (It should be possible to obtain cultures of these microorganisms from a dairy or creamery.) Is this action a type of fermentation? Are the same products formed as when yeast carries on fermentation in grape juice? Would the dairy microorganisms carry on fermentation in grape juice, and if so, would the products be the same as those produced by yeast?

C. Can yeasts survive in the presence of free oxygen? Does fermentation go on in the presence of free oxygen?

D. For library research: What kinds of industrial processes depend upon fermentation? In what ways is fermentation important in the production of foods, industrial chemical compounds, and antibiotics?

B. Glycolysis

1. Relationship to Fermentation

2. Experimental Evidence for Glycolysis

3. Outline of Process of Glycolysis

4. Location of Occurrence of Glycolysis

II. Aerobic Respiration

INTRODUCTION:

Aerobic respiration is the breakdown (or oxidation) of glucose in a very specialized organelle within the cell. In this organelle, the mitochondrion, glucose - $C_6H_{12}O_6$ fragments are dehydrogenated which means that the molecule's hydrogen atoms are removed. This removal of hydrogen atoms consititutes an oxidation reaction.

We have just studied the processes of fermentation and glycolysis which are also concerned with the breakdown of glucose to ethyl alcohol or pyruvic acid and the subsequent release of energy. The process of aerobic respiration with which we are now concerned differs from the processes of fermentation and glycolysis in that this process requires oxygen and begins with the end product of glycolysis - pyruvic acid. Therefore aerobic respiration is the complete breakdown of glucose to carbon dioxide and water and as such releases a great deal more energy.

A. Methods of Energy Release From Fuels

1. How energy Gets Into Fuels

2. How Energy is Released from fuels by Oxidative Processes

   a. Rapid Processes

   b. Slower "stepwise" Processes

B. The Kreb's Cycle

The Kreb's Cycle is the series of biochemical reactions occurring in the cell's mitochondria in which a smaller part of the glucose molecule, pyruvic acid, is broken down to carbon dioxide and water in the presence of oxygen. This "cellular oxidation" releases large amounts of energy which are then stored in the molecule ATP. It is ATP which carries the energy from place to place within the cell as it is needed for cellular growth, repair or maintenance.

1. The stages of Cellular Oxidation in the Kreb's Cycle

   a. Stage One - A Glycolytic Process

   b. Stage Two - Kreb's Cycle

      (1) Dehydrogenation - the Oxidative Process

      (2) Decarboxylation - Breaking and Rearranging of the Carbon Chain

c. Stage Three - The Uptake of Released Energy by ATP

(1) The Role and Mechanism of ATP

(2) The Pickup of Hydrogen Atoms

(3) The Transfer of Hydrogen Atoms

C. The Electron Carrier System - A Chain of Enzymes

1. Types of Enzymes Involved

a. Dehydrogenases

b. Flavoproteins

c. Cytochromes

d. Cytochrome Oxidase

2. Oxidative Phosphorylation

4. Summary of Electron Transport

Note: It is this process of transporting H atoms or the atom's electrons which generates about 90% of the energy as ATP in cellular respiration.

III. Flow Diagram of Energy Transfer From Glucose to ATP

Fermentation and Respiration

LOCALIZATION OF PATHWAYS

I. Outside the Mitochondrion

A. Fermentation - the Role of Enzymes

B. Glycolysis - Enzymes and Muscle Contractions

II. Inside the Mitochondrion

A. The Kreb's Cycle

B. Electron Transport

ENERGY BALANCE

I. The Efficiency of Energy Cycles - Fermentation vs. Respiration

A. General Flow Diagrams

1. Fermentation

2. Respiration

B. Generation of Energy as ATP - A Comparison

1. Fermentation

a. Percent Efficiency

b. Caloric Relationships

2. Respiration

a. Percent Efficiency

b. Caloric Relationships

II. Variations in Energy Content of Food Reserves

A. Rates of Respiration - A Laboratory Investigation

1. Laboratory Investigation - Fermentation and Cell Respiration

FERMENTATION AND CELL RESPIRATION

INTRODUCTION:

Two kinds of energy-releasing processes occur in cells. One is called aerobic respiration and the other, anaerobic respiration, or fermentation. In aerobic respiration, oxygen is needed to bring about a combustion of materials (usually sugars) in the cell to release energy. In anaerobic respiration, energy is released in the absence of oxygen. The essential chemical event in anaerobic respiration is the rearrangement of sugar molecules. The energy obtained from both kinds of respiration is used to make adenosine triphosphate (ATP). Also, carbon dioxide and heat energy are released.

In this investigation, you will measure the rate of aerobic respiration in a plant and the rate of anaerobic respiration in a protist, yeast.

MATERIALS:

test tubes
2-hole rubber stopper
  or corks
glass tubing
pinch clamps
rubber tubing
dropping pipettes
mineral oil
marking pencil
ring stand
cake yeast
10.0% glucose solution
Burette clamps
stirring rod
pea seedlings
soda lime
absorbent cotton
metric ruler

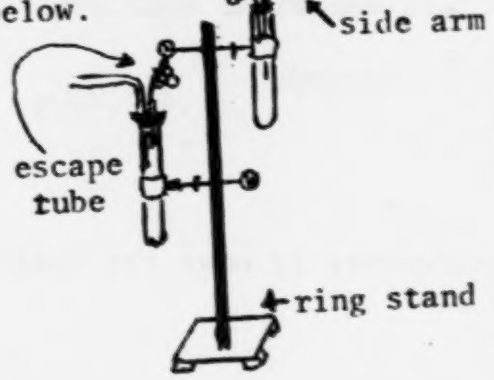
PURPOSE:

To investigate rates of respiration.

PROCEDURE:

A. You will measure the rates of respiration in terms of volumes of gas (oxygen and carbon dioxide) used or produced. The device that you will use to measure volume is called a manometer. Many types of manometers can be purchased or made in the laboratory. You will be provided with materials for assembling a simple manometer.

Using a marking pencil, mark off the side arm of the bent pieces of glass tubing into equal units of about ¼ inch in length. Assemble the manometer as shown below.



B. Add 3 ml. of water to one of the manometer test tubes. Firmly replace the stopper in the test tube. Place a drop of mineral oil into the opening of the side arm. Move the drop of mineral oil to the proximal (near) end of the side arm in the following way. The drop of mineral oil will serve as the indicator. Release the pinch clamp on the escape tube. Evacuate the air from a dropping pipette by squeezing the bulb. While squeezing the bulb of the dropping pipette, insert the glass tip into the escape tube. Release the bulb. You will draw air out of the test tube, and the drop of mineral oil should move inward. Close the tubber tubing with the pinch clamp or your fingers.

Repeat the procedure until the drop of oil is at the proximal end of the side arm. Remember to close the escape tube after each evacuation of air. When the drop of oil is in the desired position, close the escape tube with the pinch clamp. The tube you have prepared will serve as the control manometer.

C. Place a piece of yeast about the size of a small pea in the other test tube. Crumble the yeast as you put it in the tube. Add about 1 ml. (20 drops) of 10.0% glucose to the yeast in the tube. This is the experimental tube.

Replace the stopper. Working quickly, place the drop of mineral oil and adjust to proximal position as described in Step B.

D. Observe the indicator drops in both tubes. Start taking readings of movements of the indicator drops about a minute after you first notice movement in the arm of the experimental tube. Take readings every minute. Express your data in terms of numbers of units of movement of the indicator drop per minute. Subtract any movement in the control manometer from your readings. Continue to take readings until movement stops.

QUESTIONS:

1. Record your data.

Anaerobic respiration can be expressed in the following empirical equation:

$$C_6H_{12}O_6 \xrightarrow{\text{enzymes}} 2\ C_2H_5OH + 2\ CO_2 + 2 \sim p$$

Anaerobic respiration that occurs in animal tissues, such as muscle, can be expressed in this empirical equation:

$$C_6H_{12}O_6 \xrightarrow{\text{enzymes}} 2\ C_3H_6O_3 + 2 \sim p$$

QUESTIONS:

2. Why was it necessary to move the indicator drop to the proximal end of the side arm?

E. Place pea seedlings in one of the test tubes until the tube is a little more than half full. Place some cotton over the pea seedlings. Put some soda lime over the cotton. Do not put so much soda lime in the test tube that the glass tubing in the stopper dips down into it. The soda lime will absorb the carbon dioxide.

Replace the stopper and glass tubing firmly in the mouth of the test tube. Place the indicator drop at the distal (far) end of the side arm. It may be necessary to draw the drop inward a small distance to prevent it from dropping out. Prepare a control manometer with a volume of water equal to the volume of the materials in the experimental tube.

F. Allow 4-5 minutes for establishment of equilibrium in the tubes before taking readings. Take readings in terms of units of movement every 5 minutes. Subtract readings of the control manometer.

QUESTIONS:

3. Record your data.

Aerobic respiration is a more complex chemical process than anaerobic respiration. Mnay steps are involved. The anaerobic respiration of one molecule of glucose yields 2 molecules of ATP. The aerobic respiration of one molecule of glucose yeilds approximately 38 molecules of ATP. The aerobic respiration of glucose can be summed up in the following empirical equation. (The equation is a summary and by no means expresses the actual chemical events of aerobic respiration.)

$$C_6H_{12}O_6 + 6\ O_2 \xrightarrow{\text{enzymes}} 6\ CO_2 + 6\ H_2O + \text{approx. 38 ATP}$$

QUESTIONS:

4. Why was it necessary to place the indicator drop at the distal end of the side arm?

5. How could you determine the weight of the carbon dioxide given off? From the data, how could you determine the approximate weight of the oxygen used?

REVIEW QUESTIONS:

1. Why was it necessary to use a control manometer?

2. The summary equation for aerobic respiration is essentially the opposite of what process? Explain.

2. Laboratory Investigation - Respiration Quotient

a. Parallel Reading: Fermentation and Respiration

Like many other terms, fermentation and respiration are defined differently by different people. It would not be possible to repeat all these definitions here, nor would it be very useful. Most biologists probably think of fermentation as a process whereby food materials are only partially oxidized by micro-organisms; that is, some of the products still contain energy which can be released by further oxidation.

To many, respiration means the process of breathing. (The word respiration is derived from the Latin word respirare, meaning to blow back or to breathe.) Ordinarily when a physician speaks of a patient's rate of respiration, he means how many times the patient inhales (or exhales) in a minute. Many biologists define respiration as a process in which food material is broken down and most of its energy released in the cell. Those who use this definition regard alcoholic fermentation as an example of anaerobic respiration, because free oxygen is not utilized. If molecular oxygen is used, the process is called aerobic respiration.

Other biologists define respiration as a process in which energy is liberated from food materials, and in which the final oxidizing agent is molecular oxygen. If we use this definition, respiration is always an aerobic process, and since alcoholic fermentation is anaerobic, it would not be called respiration. Acetic acid fermentation (the process in which bacteria of the genus *Acetobacter* convert ethanol to acetic acid and water) is an example of fermentation which involves respiration since molecular oxygen is used. Most researchers in the field of respiration consider incomplete oxidations, such as those in acetic acid fermentation, to be respiration if they involve the oxidation of hydrogen to water.

The conversion of sugar to carbon dioxide and water by complete oxidation provides more energy than the conversion of sugar to alcohol and carbon dioxide by fermentation. The summary equations for these two processes are:

1. alcoholic fermentation of glucose:

$$C_6H_{12}O_6 \rightarrow 2\ CH_3CH_2OH + 2\ CO_2 + 54\ \text{kg calories}$$

2. respiration of glucose:

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + 686\ \text{kg calories}$$

Those organisms which can ferment sugar may have an advantage over those which cannot when free oxygen is not available, but they are at a disadvantage is they cannot carry out respiration when oxygen is available.

If molecular oxygen is available, most cells, including yeast, can oxidize pyruvic acid to carbon dioxide and water. This is accomplished by a series of enzymatic reactions which have been called the Krebs cycle, the citric acid cycle, or the tricarboxylic acid cycle.

The net result of this complex series of simple chemical reactions is the production of 38 molecules of ATP from the respiration of one molecule of glucose. By comparison, recall that a net gain of only 2 molecules of ATP results from the alcoholic fermentation of glucose.

Another respiratory mechanism has been recognized in recent years called the pentose-phosphate pathway. This mechanism is not quite as efficient as a combination of glycolysis and the Krebs cycle since only 36 molecules of ATP may be formed from a molecule of glucose. The results of a number of experiments indicated that the pentose-phosphate cycle is a common oxidative pathway in many microbes and in most plant tissue. A discussion of the pentose-phosphate cycle is beyond the scope of this reading but can be found in several recent biochemistry texts.

It may be useful to examine some of the characteristics of respiratory processes. We can measure the rate of respiration by measuring the rate of consumption of either oxygen or food, or the rate of production of carbon dioxide, water, or heat.

While respiration occurs both in the light and in the dark, the release of oxygen during photosynthesis may mask the utilization of oxygen involved in green plant respiration. Here we see the importance of the proper choice of experimental organisms. It would be extremely difficult to measure respiration in a photosynthesizing green plant. For this reason, germinating seeds, which have not yet begun photosynthesis, are often used in studying respiration.

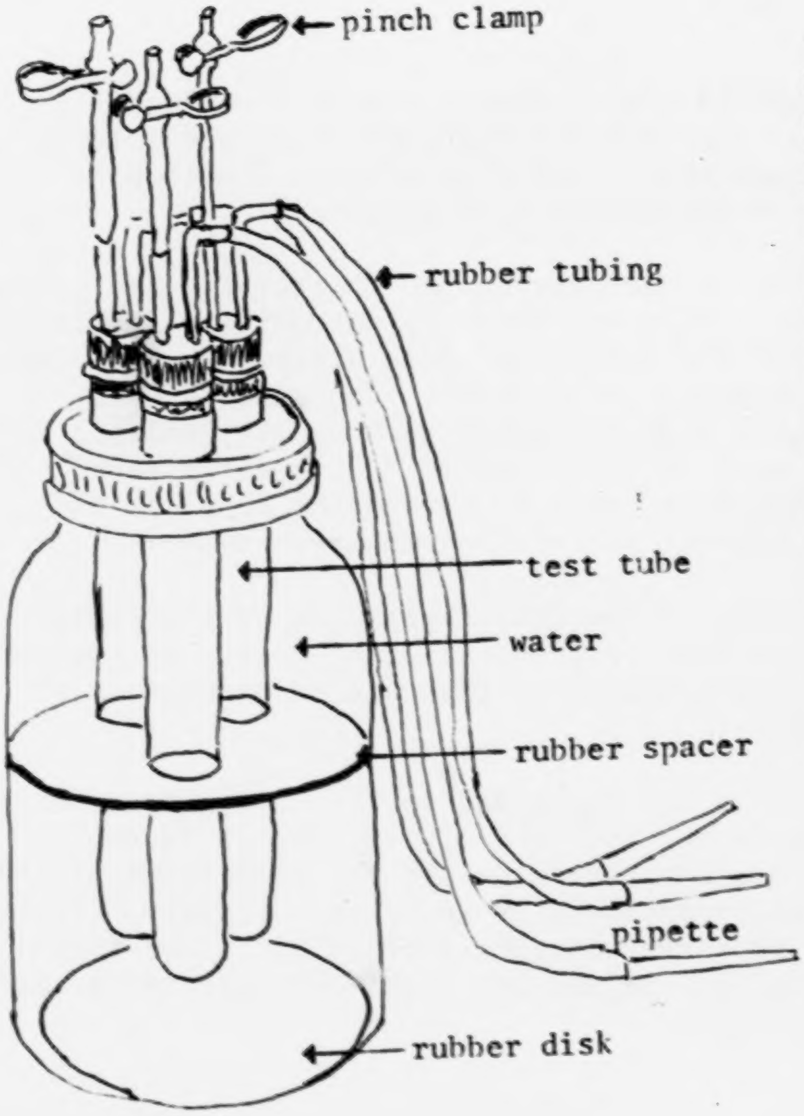
b. Laboratory Investigation - Measuring Rates of Respiration

MEASURING RATES OF RESPIRATION

INTRODUCTION:

Precise measurements of the rate of respiration require elaborate equipment. We can, however, obtain reasonably accurate measurements using simpler methods. This is often done by placing the living materials in a closed system and measuring the amount of oxygen which goes into the system or the amount of carbon dioxide which comes out. By using suitable techniques, we can measure the amounts of one or both of these gases over a given period of time and determine the respiration rate. A simple volumeter can be set up as shown on page 70.

The volumeter should be arranged as follows. The material for which respiration measurements are desired is placed in one or more test tubes of uniform size. Each tube contains a stopper and pipette as shown in the illustration. One of the test tubes contains an inert material such as glass beads or washed gravel and is used to correct changes in temperature and pressure which cannot be completely controlled in the system.



VOLUMETER

This tube is called a thermobarometer. Equal volumes of both test and inert materials must be placed in all the tubes. This precaution is necessary to assure that an equal volume of air is present in each tube. A very small drop of colored liquid is inserted into each pipette at its outer end. This closes the tube, so that if there is any change in the volume of gas left in the tube, the drop of colored liquid will move. (The direction of movement depends on whether the volume of gas in the system increases or decreases.) The distance of movement over a given period of time can be read from a ruler placed on the side of the pipette. The volume of gas added or removed from the system can be read directly from the calibrated pipette.

In attempting to measure respiration with the equipment just described, we must take into consideration not only that oxygen goes into the living material (and thus out of our volumeter test tube), but also that carbon dioxide comes out of the living material (and thus enters into the volumeter test tube). If we are to measure the oxygen uptake in our respiring material we must first trap the carbon dioxide as it evolves. This can be done by adding any substance (ascarite is commonly used) which will absorb the carbon dioxide as fast as it is evolved. Efficient removal prevents the carbon dioxide from being added to the volume of gas in the tube.

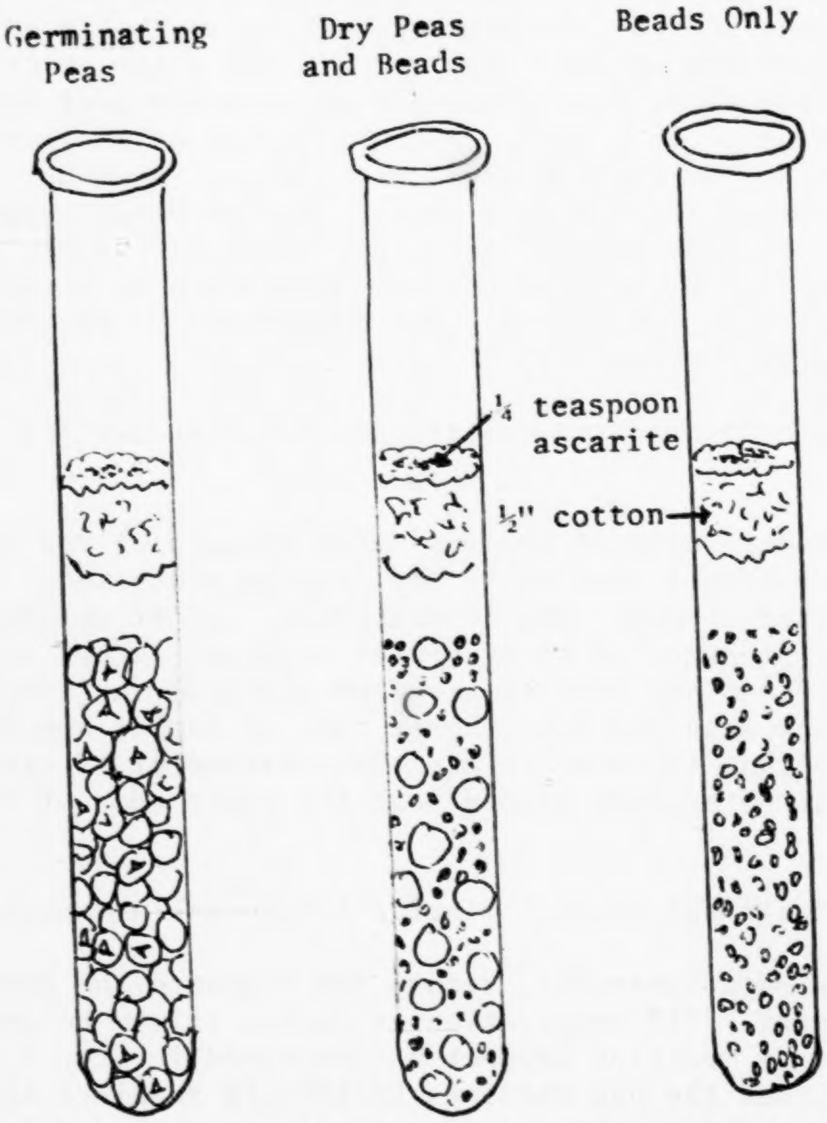
Each team should set up one volumeter and compare the respiration of dry seeds with those which have been soaked for 24 hours. The work involved in setting up the volumeter and in obtaining measurements is difficult to complete in one laboratory period. It is very important that certain preparations be made in advance, and that each member of the team understands clearly what is to be done.

MATERIALS: (per team)

one volumeter (complete)
one thermometer
one hundred Alaska pea seeds
germination tray
100 ml. graduate cylinder
glass beads
three beakers, 150 ml.
solution of dye
cotton
ascarite
eye dropper

PROCEDURE DAY I:

Each team should place 40 pea seeds in a germination tray between layers of wet paper towels and allow them to soak for 24 hours. (label the trays as to team, class, experiment, and date.)



Volumeter Tubes after Preparation

PROCEDURE DAY II:

1. Determine the volume of the 40 soaked seeds. This volume will be used as a standard for preparing materials for the other two test tubes in the volumeter. (Volumes of solid objects, including seeds, can be determined readily by adding them to a measured volume of water in a graduated cylinder and reading the volume of displaced water.)

2. Determine how many glass beads must be put in the tube with the dry seeds so that the volume of air in the tubes with soaked and dry seeds will be the same. To do this, place 25 ml. of water in a 100 ml. graduate cylinder. Add the dry seeds. Then add enough beads so that the increase of the water level in the cylinder containing both seeds and beads is equal to the volume of the seeds soaked for 24 hours. Dry the 40 seeds and the glass beads by blotting them with paper toweling or cleansing tissue. Place the dried seeds and beads together in a beaker. Label the beaker and store it in the laboratory until you are ready to use the volumeter the following day.

3. Obtain the same volume of glass beads as that determined for use for the soaked pea seeds. Place these in a beaker, label the beaker, and store it in the laboratory until you are ready to set up the volumeter on the third day.

4. Mix about 25 ml. of a dilute solution of vegetable dye (food coloring) in water and add a drop of detergent.

5. Set up the volumeter as illustrated on page 70. Add water to the jar in which the test tubes are immersed, but do not add anything to the test tubes.

PROCEDURE DAY III:

1. Remove the stoppers from each of the three test tubes. Add the 40 soaked pea seeds to one tube; add the dry pea seeds and glass beads which you measured out in Step 2 to the second tube; and add the glass beads measured out in Step 3 to the third tube. Loosely pack cotton over the material in each tube to a depth of ½ inch. Add ¼ teaspoon of ascarite or sodium hydroxide to the top of the cotton in each tube. CAUTION: Ascarite is caustic. Be very careful not to get it on your hands, your body, or on your clothes. If some is spilled, clean it up with a dry paper towel or paper cleansing tissue. Do not use damp cloth or paper as ascarite reacts strongly with water. The tube should now be packed as illustrated in the diagram on page 71.

2. Replace the stoppers and arrange the pipettes so that they are level on the table.

3. With a dropper, add a small drop of colored water to each of the three pipettes. (See Step 4 of Procedure, Day II.) The diagram shows setup of stopper and pipettes attached to each tube in volumeter. After colored water indicator has been introduced at outer end of pipette, it can be adjusted by opening pinch clamp and drawing air from system or pushing it into system with eye dropper inserted into rubber tube at top of apparatus. Adjust the marker drops so that the drop in the thermobarometer is centered in the pipette and the other drops are placed near the outer ends of the pipettes.

4. Allow the apparatus to sit for about 5 minutes before making measurements.

5. For 20 minutes, at 2 minute intervals, record the distance the drop moves from its starting point. (If respiration is rapid, it may be necessary to readjust the drop with the medicine dropper as described in Step 3. If readjustment is necessary, add the new readings to the old readings so that the total change during the time of the experiment will be recorded.) Record your results in a table form.

NOTE: If the drop in the thermobarometer pipette moves toward the test tube, subtract the distance it moves from the distance the drop moves in each of the other pipettes. If the drop in the thermobarometer pipette moves away from the test tube, add the distance it moves to the distance the drop moves in each of the other pipettes.

The readings in each case should be recorded as the change in volume from the original reading. If the observed volumes are corrected to volumes at standard temperature and pressure, the equivalent weights of glucose used may be calculated with greater accuracy.

QUESTIONS FOR DISCUSSION:

1. What is the effect of moisture on the germination of pea seeds?
2. Would adding more water to the soaked seeds result in an increased rate of respiration?
3. What is the significance of the difference in the respiration rate of dry seeds compared with that of germinating seeds as far as the ability of the seed to survive in nature is concerned?

INVESTIGATIONS FOR FURTHER STUDY:

1. Design a modification of this experiment which will allow you to measure the amount of carbon dioxide given off by seeds during respiration.
2. Measure the effects of temperature on the respiratory rates of two different insects.
3. Compare the rates of respiration of different kinds of plant tissues. You might use tissues such as carrot root, potato tuber, or leaves. If green tissues are used, keep them dark by use of black paper or cloth.

---

c. Pattern of Inquiry

(1) The Respiratory Ratio - After completing the investigation of Measuring Rates of Respiration, a student wished to study other aspects of respiration in seeds. He decided to see if the respiratory quotient or ratio is different in different kinds of seeds. The respiratory quotient is defined as the ratio between the volume of carbon dioxide produced and the volume of oxygen used ($RQ = CO_2/O_2$). He experimented with seeds of wheat and castor bean, and obtained the results shown below.

Milliliter of Carbon Dioxide Produced		Milliliters of Oxygen Used	
Wheat	Castor Bean	Wheat	Castor Bean
11.5	7.0	11.3	9.0
13.7	4.5	13.9	7.0
5.5	20.0	5.2	28.5
20.0	14.5	19.4	19.5
17.6	3.1	17.9	4.2
6.2	8.0	6.4	10.5
7.8	10.0	8.0	15.0
15.7	12.5	15.8	18.3

Plot the data for each species on graph paper with milliliters of carbon dioxide produced as the ordinate and milliliters of oxygen used as the abscissa. Can you connect all of the points for either species with a straight line? Why?

(2) Statistical Evaluation of Data - The Respiratory Ratio

Now draw a straight line which best fits the points which you have plotted for the data for wheat seeds, and another straight line for the data for castor bean seeds.

Follow the usual custom and consider the values on the horizontal axis (the abscissa) as x, and those on the vertical axis (the ordinate) as y. For the wheat seeds you can see that the straight line indicates that for each volume of oxygen used, a like volume of carbon dioxide was released. The ratio of y/x (that is, CO_2/O_2) is the respiratory ratio, and in this case it is equal to 1. We can rewrite y/x = 1 as y = x, and this states that in simple form what we have just noted, i.e., the volume of the carbon dioxide liberated equals the volume of oxygen used.

We say that the relationship between the volume of carbon dioxide liberated and that of the volume of oxygen used in linear, because all of the points approximate a straight line. But note that while the data for the castor bean seeds is also linear, in that case y/x does not equal 1 (that is, y does not equal x). What is the value for y/x for the castor bean seeds?

Consider the equation y/x = 0.71. What is the value of y in terms of x? What is the value of x in terms of y?

Note that we are saying that for each value of x, y will be equal to a given multiple (or fraction) of x. This will always be true if the relationship between x and y is linear. If the multiple (or fraction) does not change, we can write y = kx, where k is a constant. In the data for the castor beans, k = o.71; for the wheat grains, k = 1. When we have a linear relationship as in these experiments, we often refer to k as the slope of the line, because k tells us how steeply the line slopes in relation to the x axis. In the case of the castor bean seeds, for each increase of one unit on the x axis there was an increase of 0.71 units on the y axis. When the values are plotted as they are here, the respiratory quotient, CO_2/O_2, is equal to the slope.

What is the respiratory quotient, for the germinating wheat grains?

The data indicate that there was a constant ratio between the amount of carbon dioxide released and the amount of oxygen used in germinating wheat grains and in castor bean seeds. They also indicate that this ratio is different for the two kinds of seeds. Although it may not have been brought out in the discussion on respiration, cells may use different kinds of food materials in their respiratory processes. What explanation can you give for the difference in the respiratory quotient in the two kinds of seeds?

The composition of starch is often shown as $(C_6H_{10}O_5)_n$. While castor oil is a mixture, the formula $C_{57}H_{104}O_8$ represents a reasonable average for its constituents. Assume that in respiration both starch and fats are completely oxidized to carbon dioxide and water. Write the summary equations for the oxidation of each, and from these equations determine the theoretical respiratory quotients for each kind of food.

Another student conducted an experiment similar to the one described in the first part of this Pattern of Inquiry. Instead of measuring the volumes of carbon dioxide produced and oxygen used, he used a different kind of apparatus and obtained the weights of each. For the germinating wheat grains he obtained the following data:

Milligrams of O_2 Used x	Milligrams of CO_2 Produced y	Milligrams of CO_2 Produced/Milligram O_2 Used y/x
17.0	26.3	1.54
7.5	9.8	1.31
9.7	14.7	1.52
12.0	14.7	1.44
21.4	32.1	1.50
15.3	18.6	1.29
6.3	8.2	1.30
24.0	31.2	1.30

Plot the weights of carbon dioxide produced against the weights of oxygen used. Again, except for experimental error, the points fall on a straight line. But note that while in the data for wheat grains in the first problem, y was equal to x, this is not true here. What is the slope of the line in this case? What is the respiratory quotient? Explain.

---

3. Chemical Composition of Food Reserves - Laboratory Investigation

DETECTION OF ORGANIC NUTRIENTS

INTRODUCTION:

Cells are alive and therefore carry on such life processes as growth, reproductive, respiration, and excretion. Specialized cells may perform other functions. Certain gland cells manufacture and secrete hormones. Plant cells with chloroplasts carry on photosynthesis. All of these activities require energy which comes from certain nutrients.

Nutrients are the basic materials or building block substances, of which the main types are (a) carbohydrates which include starches and sugars:
(b) fats such as vegetable oil, glycerol, tallow, cholesterol, etc.;
(c) proteins which provide animals with their chief sources of nitrogen;
(e) minerals such as salt, iron, potassium, and phosphorus; and finally,
(f) water.

Many biologists divide the above list into two groups: foods and mineral nutrients. According to this classification the term food includes only organic compounds that can be respired to yield energy and which can be used in assimilation. Foods, then would include fats, carbohydrates, and proteins. These three groups of substances are manufactured by plants from simple sugars and certain additional substances obtained from the soil. Among these additional substances are such nonmetallic elements as nitrogen, phosphorus, and sulfur and such metallic elements as potassium, magnesium, and calcium. These, and several other elements in compound form, make up the mineral nutrient or inorganic nutrient requirements of organisms. Very generally speaking, both groups of substances amy be called nutrients, but only fats, carbohydrates, and proteins are classified as foods.

These nutrients are rarely found in a pure state but rather are mixed together to form such complexes as bread, milk, meat, fruit, etc. These complexes of nutrients are what we normally call food. In a food such as a carrot or a banana, the various nutrients retain their chemical identities; therefore their presence can be shown by chemical detectors.

In this investigation you will be given the opportunity to use some of these chemical detectors to find out what nutrients are present in certain food materials. The nutrients you will look for are starches, sugars, fats, and proteins. The tests for vitamins and minerals are too difficult or time-consuming to be done during this laboratory period.

In testing for chemical content it is absolutely essential for the glassware to be clean. Therefore, if the test tubes you gather are not clean, wash them and rinse them thoroughly.

The next important step in a chemical analysis is validating each reagent against a known type of material that the reagent tests. Once this is done, the reagent can be used on any food as a test for that particular nutrient.

MATERIALS:

iodine solution
Bunsen burner with hot H_2O bath
miscellaneous foods: bread, meat, milk, banana, etc.
Benedict's or Fehling's solution
Biuret reagent

For Each Two Students:

two clean test tubes
beaker
glass stirring rod

PROCEDURE:

Select the food to test.

Place some of it at the bottom of a test tube to a depth of about ½ inch. (you may have to use a glass rod to push the food down).

Add water to the food in the tube up to a level of about 2 inches (tests for starch, sugar, or protein require the presence of water).

Shake the tube thoroughly to mix the water with the food. Note: Prepare as many tubes of each food as you are going to test for different nutrients. Thus, if you are going to test bread for starch, sugar, and protein - prepare 3 tubes containing bread.

Conduct the tests as follows:

For Starch - Add 5 drops of iodine solution and shake the tube to mix the contents. A blue-black color indicates that starch is present. Record your observations.

For Sugar - (1) Add 20 drops (or two medicine droppers full) of Fehling's or Benedict's solution. (2) Shake the tube to mix the contents of the tube thoroughly. (3) Place in a beaker of boiling water for 5 minutes or heat gently to boiling over a flame.

CAUTION: SHAKE THE TUBE WHILE HEATING; OTHERWISE THE TUBE MAY CRACK. DO NOT HAVE THE MOUTH OF THE TUBE FACING YOURSELF OR ANYONE NEAR YOU. THE HOT MATERIAL MAY BOIL VIOLENTLY AND BE SHOT OUT OF THE TUBE INTO SOMEONE'S FACE.

A bright red-orange or yellow color indicates the presence of sugar. Record your observation.

For Protein - (1) Prepare another tube containing just water to a depth of about 2 inches. (2) Add 10 drops of Biuret reagent to this tube containing your food sample. A violet color indicates the presence of a protein. Record your observation.

Note: The "water tube" is a good check, since it is sometimes difficult to distinguish the violet color from the original blue color of the Biuret reagent without comparing them.

For Fats - As you know, fats do not dissolve in water. Therefore you do not add water to the food sample when you test a food for fat. Simply rub (if the food is solid) or spill (if the food is liquid) the food on a piece of paper. If the food is mixed with water the paper will get wet. In this case allow the paper to dry. Then hold the paper up to the light. A relatively permanent translucent spot indicates the presence of fat. Record your observations.

Note: When a food contains a very small proportion of fat it may escape detection by the method just described. The fat in the food may, however, be detected in the following way: Some liquid in which fat is soluble, such as ether, is mixed with the food in a test tube and the mixture is shaken, The small amount of fat in the mixture becomes concentrated in the ether. This liquid, being lighter than water, rises to the top where it can be poured off onto a piece of paper. The ether then evaporates leaving the fat on the surface of the paper. This results in a translucent spot.

IV A APPENDIX

TABLE OF APPENDICES

Logarithms: A Review . . . . APPENDIX A

Computation With Logarithms . . . . B

Table of Four-Place Logarithms. C

Trigonometric Functions . . . . D

Operation of the Spectronic 20 for Colorimetry . . E

La Pine 203-92 Portable Battery-Operated pH Meter F

Cenco 021662 Electronic pH meter. . . . . G

Acid-Base Indicators . . . . H

Operation of the Ostwald Viscosimeter I

Operation of the Heathkit Oscilloscope - Stimulator (Impscope) . . . . .J

Preparation of Solutions of Known Concentration in Terms of Molarity or Normality . . . . . .K

Preparation of Standard Buffers L

Procedures for Obtaining Titration Curves . . . . .M

Table of Conjugate Acid-Base Pairs Including Acid-Ionization Constants . . . . .N

Heats of Combustion of Some Common Organic Compound in Calories per Mole . . . . .O

Physical Quantities and Units . . . . .P

Physical Constants . . . . Q

Conversion Factors . . . . R

Periodic Chart of the Elements . . . . S

APPENDIX A

LOGARITHMS: A REVIEW

A logarithm is an exponent, or power, to which some base is raised. If b is any positive number, different from 1, and $b^n = x$, then the exponent n is called the logarithm of x to the base b: $\log_b x = n$

Examples are as follows:

$\log_3 9 = 2$ read "logarithm of 9 to the base 3 is 2" because $3^2 = 9$
$\log_2 2 = 1$ " " " 2 " " " 2 is 1 " $2^1 = 2$
$\log_2 8 = 3$ " " " 8 " " " 2 " 3 " $2^3 = 8$
$\log_2 16 = 4$ " " " 16 " " " 2 " 4 " $2^4 = 16$
$\log_{10} 100 = 2$ " " " 100 " " 10 " 2 " $10^2 = 100$
$\log_{10} 0.001 = -3$ .001 " " 10 " -3 " $10^{-3} = .001$
$\log_b x = n$ x b " n $b^n = x$

Tables for $\log_2$ are not readily found, but tables for logarithms to the base 10 ($\log_{10}$) are quite commonly used. The logarithms based upon 10 are called common logarithms. Conversion from $\log_{10}$ to logarithms to some other base is possible only after we become familiar with common logarithms.

The following is a simple table of common logarithms:

x:	.0001	.001	.01	.1	1	10	100	1000	10000
log x:	-4	-3	-2	-1	0	1	2	3	4

but logarithms may not always be whole numbers, for example, consider the number 382. Because it is between 100 and 1000, its log must be between 2 and 3 since $10^2 = 100$ and $10^3 = 1000$

$$\log 382 = 2.5821$$

or in exponential form,

$$10^{2.5821} = 382$$

Now how was the logarithm of 382 determined?

First of all, note any logarithm consists of 2 parts;

an integer, called the characteristic, and
a decimal, called the mantissa

$$\underset{\text{characteristic}}{2}.\underset{\text{mantissa}}{5821}$$

The characteristic is found by noting the position of the number's decimal point. For this, the following three rules apply:

1. If the decimal point of the number immediately follows its first digit, the characteristic of the logarithm of that number is zero. Note that the logarithm of any number from 1 to 10, but not including 10, has as its characteristic, zero.

2. If the decimal point appears after the second digit, the characteristic of its logarithm is 1, if after 3 digits, it is 2; if after 4 digits, it is 3, etc. This is why the characteristic of log 382 is 2.

3. If the decimal point appears immediately before the first non-zero digit, the characteristic of its logarithm is -1, sometimes denoted

as $\bar{1}$; if there is one zero between the decimal point and the first digit, the characteristic is $\bar{2}$, etc.

Example: log .008 = -3 + .9031

or $\bar{3}$.9031

or 10-3 + .9031-10 = 7.9031-10 = -2.0969

Note that the characteristic of $\log_{10}$ 0.008 must be between -3 and -2 since $\log_{10}$ 0.001 = -3 and $\log_{10}$ 0.010 = -2 Log_{10} 0.008 = -3 + .9031 does not mean that it equals -3.9031 since the latter would turn out to be between -3 and -4 instead of between -3 and -2.

SAMPLE PROBLEMS:

Find the characteristic of the logarithm for each of the following numbers.

1) 1000

2) 159

3) .5230

4) 5,230,000

5) .00007

6) 6.2380

7) .00523

8) 43.4

Finding the mantissa of the logarithm of a number:

Going back to our original example, log 382 = 2.5821

It is clear that the logarithm of 382 must be between 2 and 3 since 382 is between 10^2 = 100 and 10^3 = 1000. Neither the digit 2 nor the digit 3 can alone express the logarithm to the base 10 of 382. Such a logarithm has to be a number somewhere between 2 and 3 and is expressed as the decimal .5821. This decimal is called the mantissa of the logarithm and there are two ways of finding it.

Tables can be used to find the mantissa of a common logarithm. In the left hand column, find the first two digits of the number for which you want to find the mantissa. Then find the 3rd digit of the number in the top horizontal column. The mantissa is then located at the junction of the two rows you have found.

Thus: log 382 = 2.5821

or in exponential terms: $10^{2.5821}$ = 382

If there is a fourth significant digit in the number whose logarithm is being looked for, round off to three significant digits or use tables for 5-place logarithms.

SAMPLE PROBLEMS:

9) log 274

10) log 0.00458

11) log 1,378,000

12) log 124

13) log 0.0124

14) log 39.6

15) log .0435

16) log 0.000346

17) log 360

18) log .005

The tables can also be used to convert a logarithm into its original number, or antilogarithm.

Example: Find the antilogarithm of $\bar{2}.6812$

(that is, find the number whose logarithm is $\bar{2}.6812$).

The mantissa, 0.6812 represents the digits 480 on the log table. Since the characteristic is $\bar{2}$, the antilogarithm of $\bar{2}.6812$ is .0480, that is, $10^{\bar{2}.6812} = 0.0480$.

SAMPLE PROBLEMS:

19) antilog 1.5211

20) antilog 9.5211-10

21) antilog 1.6972

22) antilog $\bar{2}.3729$

23) antilog 9.7364-10

24) antilog 3.9717

25) antilog $\bar{3}.9717$

The other way to find the logarithm of a number is with the D-L combination of scales on the slide rule.

To find the logarithm of a number, set the D and L scales in exact register with one another, locate the significant digits on the D scale and the required logarithm will be found by use of the cursor in register on the L scale. The characteristic of the logarithm is found from the position of the decimal point in the same way as it is determined when a log table is used.

To find the number when given its logarithm, locate the mantissa of the logarithm upon the L scale and read off the significant digits of the number in register on the D scale. The decimal point for the number is fixed by the characteristic of the given logarithm in the usual manner.

APPENDIX B

COMPUTATION WITH LOGARITHMS

Once the use of the tables in finding logarithms and antilogarithms has been mastered, one is now ready to begin using logarithms as tools for computation. Such work is made simple on consideration of the meaning of each of the following theorems:

Theorem 1. $\log_b (xw) = \log_b x + \log_b w$

Theorem 2. $\log_b (x/w) = \log_b x - \log_b w$

Theorem 3. $\log_b (x^r) = r \log_b x$

These theorems are simply translations from the language of exponents into the language of logarithms. The corresponding laws for exponents are as follows:

$$b^y \; b^w = b^{y+u}$$

$$b^y / b^w = b^{y-u}$$

$$(b^y)^r = b^{yr}$$

Proofs of the three theorems will not be given here but can be found in any math book on the subject.

1st EXAMPLE;

Calculate $\dfrac{(3.21)\ (52.8)}{294}$

Call the result x. Then by theorems 1 and 2 above,

$$\log x = \log \frac{(3.21)\ (52.8)}{294} = \log 3.21 + \log 52.8 - \log 294$$

NOW

$$\begin{aligned}
\log 3.21 &= 0.5065 \\
\log 52.8 &= \underline{1.7226} \\
\log 3.21 + \log 52.8 &= 2.2291 \\
\log 294 &= \underline{2.4683} \quad \text{to subtract} \\
\log x &= -0.2392
\end{aligned}$$

A negative exponent can be converted to a logarithm with a negative characteristic and a positive mantissa in the following manner:

$$\begin{aligned}
y - 10 &= -\,0.2392 \qquad \text{where } y-10 = \log x \\
y &= -\,0.2392 + 10 \\
y &= 9.7608
\end{aligned}$$

thus: $\log x = 9.7608-10$ or $\bar{1}.7608$

hence $x = \text{antilog } \bar{1}.7608 = 0.576$

By using logarithms, the problem has been done in a much shorter time than it would have been by straightforward arithmetic. The use of logarithms shortens computation time because the cumbersome, time-consuming operations of multiplication, division and root-extraction are replaced by simpler operations of adding logarithms for multiplication, subtracting them for division and dividing them by the root-index for root-extraction. In so doing, every positive number is represented as a power of 10:

$3.21 = 10^{0.5065}$ $\quad 52.8 = 1.7226$ $\quad 294 = 10^{2.4683}$

$$\frac{(3.21)\ (52.8)}{294} = \frac{(10^{0.5065})\ (10^{1.7226})}{10^{2.4683}} = 10^{0.5065\ +\ 1.7226\ -\ 2.4683}$$

$$= 10^{-0.2392} = 10^{9.7608-10} \quad \text{or } 10^{\bar{1}.7608} = 0.576$$

Note that this problem could be done even faster on the slide-rule, but in multiplying and dividing on the slide-rule, one is still carrying out the same operations since the C and D scales are scales of logarithms.

Consider the next example (#2)

Find $100\ (1.02)^{64}$, letting the result be called x.

Then by theorems 1 and 3:

$$\log x = \log 100 + 64 \log 1.02$$

$$= 2 + 64\ (0.0086) = 2.5504$$

Hence, $x = \text{antilog } 2.5504 = 355$

If the above problem is attempted with the slide-rule alone, the value of using logarithms for computation becomes quickly appreciated.

3rd EXAMPLE

Find $\sqrt[4]{329}$ Let x be the result.

$x = \sqrt[4]{329} = 329^{1/4}$

By theorem 3:

$\log x = \frac{1}{4} \log 329 = \frac{1}{4}\ (2.5172) = 0.6293$

hence $x = \text{antilog } 0.6293 = 4.26$

SAMPLE PROBLEMS:

Evaluate by means of logarithms:

1. $\frac{(29.7)\ (3.4)}{572}$

2. $\frac{(492)\ (6.82)^2}{(59)^3}$

3. $\sqrt[3]{79200}$

4. $\sqrt[5]{0.00759}$

5. $321\ (1.04)^{19}$

FOUR-PLACE LOGARITHMS

N	0	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996
	0	1	2	3	4	5	6	7	8	9

Published and Copyright 1956 by The Welch Scientific Company, 7300 North Linder Avenue, Skokie, Illinois 60076

Catalog No. 592

TRIGONOMETRIC FUNCTIONS

	SIN						
ANG.	0′	12′	24′	36′	48′	60′	
0	.0000	.0035	.0070	.0105	.0140	.0175	89
1	.0175	.0209	.0244	.0279	.0314	.0349	88
2	.0349	.0384	.0419	.0454	.0488	.0523	87
3	.0523	.0558	.0593	.0628	.0663	.0698	86
4	.0698	.0732	.0767	.0802	.0837	.0872	85
5	.0872	.0906	.0941	.0976	.1011	.1045	84
6	.1045	.1080	.1115	.1149	.1184	.1219	83
7	.1219	.1253	.1288	.1323	.1357	.1392	82
8	.1392	.1426	.1461	.1495	.1530	.1564	81
9	.1564	.1599	.1633	.1668	.1702	.1736	80
10	.1736	.1771	.1805	.1840	.1874	.1908	79
11	.1908	.1942	.1977	.2011	.2045	.2079	78
12	.2079	.2113	.2147	.2181	.2215	.2250	77
13	.2250	.2284	.2317	.2351	.2385	.2419	76
14	.2419	.2453	.2487	.2521	.2554	.2588	75
15	.2588	.2622	.2656	.2689	.2723	.2756	74
16	.2756	.2790	.2823	.2857	.2890	.2924	73
17	.2924	.2957	.2990	.3024	.3057	.3090	72
18	.3090	.3123	.3156	.3190	.3223	.3256	71
19	.3256	.3289	.3322	.3355	.3387	.3420	70
20	.3420	.3453	.3486	.3518	.3551	.3584	69
21	.3584	.3616	.3649	.3681	.3714	.3746	68
22	.3746	.3778	.3811	.3843	.3875	.3907	67
23	.3907	.3939	.3971	.4003	.4035	.4067	66
24	.4067	.4099	.4131	.4163	.4195	.4226	65
25	.4226	.4258	.4289	.4321	.4352	.4384	64
26	.4384	.4415	.4446	.4478	.4509	.4540	63
27	.4540	.4571	.4602	.4633	.4664	.4695	62
28	.4695	.4726	.4756	.4787	.4818	.4848	61
29	.4848	.4879	.4909	.4939	.4970	.5000	60
30	.5000	.5030	.5060	.5090	.5120	.5150	59
31	.5150	.5180	.5210	.5240	.5270	.5299	58
32	.5299	.5329	.5358	.5388	.5417	.5446	57
33	.5446	.5476	.5505	.5534	.5563	.5592	56
34	.5592	.5621	.5650	.5678	.5707	.5736	55
35	.5736	.5764	.5793	.5821	.5850	.5878	54
36	.5878	.5906	.5934	.5962	.5990	.6018	53
37	.6018	.6046	.6074	.6101	.6129	.6157	52
38	.6157	.6184	.6211	.6239	.6266	.6293	51
39	.6293	.6320	.6347	.6374	.6401	.6428	50
40	.6428	.6455	.6481	.6508	.6534	.6561	49
41	.6561	.6587	.6613	.6639	.6665	.6691	48
42	.6691	.6717	.6743	.6769	.6794	.6820	47
43	.6820	.6845	.6871	.6896	.6921	.6947	46
44	.6947	.6972	.6997	.7022	.7046	.7071	45
45	.7071	.7096	.7120	.7145	.7169	.7193	44
	60′	48′	36′	24′	12′	0′	ANG.
						COS	

	SIN						
ANG.	0′	12′	24′	36′	48′	60′	
46	.7193	.7218	.7242	.7266	.7290	.7314	43
47	.7314	.7337	.7361	.7385	.7408	.7431	42
48	.7431	.7455	.7478	.7501	.7524	.7547	41
49	.7547	.7570	.7593	.7615	.7638	.7660	40
50	.7660	.7683	.7705	.7727	.7749	.7771	39
51	.7771	.7793	.7815	.7837	.7859	.7880	38
52	.7880	.7902	.7923	.7944	.7965	.7986	37
53	.7986	.8007	.8028	.8049	.8070	.8090	36
54	.8090	.8111	.8131	.8151	.8171	.8192	35
55	.8192	.8211	.8231	.8251	.8271	.8290	34
56	.8290	.8310	.8329	.8348	.8368	.8387	33
57	.8387	.8406	.8425	.8443	.8462	.8480	32
58	.8480	.8499	.8517	.8536	.8554	.8572	31
59	.8572	.8590	.8607	.8625	.8643	.8660	30
60	.8660	.8678	.8695	.8712	.8729	.8746	29
61	.8746	.8763	.8780	.8796	.8813	.8829	28
62	.8829	.8846	.8862	.8878	.8894	.8910	27
63	.8910	.8926	.8942	.8957	.8973	.8988	26
64	.8988	.9003	.9018	.9033	.9048	.9063	25
65	.9063	.9078	.9092	.9107	.9121	.9135	24
66	.9135	.9150	.9164	.9178	.9191	.9205	23
67	.9205	.9219	.9232	.9245	.9259	.9272	22
68	.9272	.9285	.9298	.9311	.9323	.9336	21
69	.9336	.9348	.9361	.9373	.9385	.9397	20
70	.9397	.9409	.9421	.9432	.9444	.9455	19
71	.9455	.9466	.9478	.9489	.9500	.9511	18
72	.9511	.9521	.9532	.9542	.9553	.9563	17
73	.9563	.9573	.9583	.9593	.9603	.9613	16
74	.9613	.9622	.9632	.9641	.9650	.9659	15
75	.9659	.9668	.9677	.9686	.9694	.9703	14
76	.9703	.9711	.9720	.9728	.9736	.9744	13
77	.9744	.9751	.9759	.9767	.9774	.9781	12
78	.9781	.9789	.9796	.9803	.9810	.9816	11
79	.9816	.9823	.9829	.9836	.9842	.9848	10
80	.9848	.9854	.9860	.9866	.9871	.9877	9
81	.9877	.9882	.9888	.9893	.9898	.9903	8
82	.9903	.9907	.9912	.9917	.9921	.9925	7
83	.9925	.9930	.9934	.9938	.9942	.9945	6
84	.9945	.9949	.9952	.9956	.9959	.9962	5
85	.9962	.9965	.9968	.9971	.9973	.9976	4
86	.9976	.9978	.9980	.9982	.9984	.9986	3
87	.9986	.9988	.9990	.9991	.9993	.9994	2
88	.9994	.9995	.9996	.9997	.9998	.9998	1
89	.9998	.9999	.9999	1.000	1.000	1.000	0
90	1.000						
	60′	48′	36′	24′	12′	0′	ANG.
						COS	

	TAN						
ANG.	0′	12′	24′	36′	48′	60′	
0	.0000	.0035	.0070	.0105	.0140	.0175	89
1	.0175	.0209	.0244	.0279	.0314	.0349	88
2	.0349	.0384	.0419	.0454	.0489	.0524	87
3	.0524	.0559	.0594	.0629	.0664	.0699	86
4	.0699	.0734	.0769	.0805	.0840	.0875	85
5	.0875	.0910	.0945	.0981	.1016	.1051	84
6	.1051	.1086	.1122	.1157	.1192	.1228	83
7	.1228	.1263	.1299	.1334	.1370	.1405	82
8	.1405	.1441	.1477	.1512	.1548	.1584	81
9	.1584	.1620	.1655	.1691	.1727	.1763	80
10	.1763	.1799	.1835	.1871	.1908	.1944	79
11	.1944	.1980	.2016	.2053	.2089	.2126	78
12	.2126	.2162	.2199	.2235	.2272	.2309	77
13	.2309	.2345	.2382	.2419	.2456	.2493	76
14	.2493	.2530	.2568	.2605	.2642	.2679	75
15	.2679	.2717	.2754	.2792	.2830	.2867	74
16	.2867	.2905	.2943	.2981	.3019	.3057	73
17	.3057	.3096	.3134	.3172	.3211	.3249	72
18	.3249	.3288	.3327	.3365	.3404	.3443	71
19	.3443	.3482	.3522	.3561	.3600	.3640	70
20	.3640	.3679	.3719	.3759	.3799	.3839	69
21	.3839	.3879	.3919	.3959	.4000	.4040	68
22	.4040	.4081	.4122	.4163	.4204	.4245	67
23	.4245	.4266	.4327	.4369	.4411	.4452	66
24	.4452	.4494	.4536	.4578	.4621	.4663	65
25	.4663	.4706	.4748	.4791	.4834	.4877	64
26	.4877	.4921	.4964	.5008	.5051	.5095	63
27	.5095	.5139	.5184	.5228	.5272	.5317	62
28	.5317	.5362	.5407	.5452	.5498	.5543	61
29	.5543	.5589	.5635	.5681	.5727	.5774	60
30	.5774	.5820	.5867	.5914	.5961	.6009	59
31	.6009	.6056	.6104	.6152	.6200	.6249	58
32	.6249	.6297	.6346	.6395	.6445	.6494	57
33	.6494	.6544	.6594	.6644	.6694	.6745	56
34	.6745	.6796	.6847	.6899	.6950	.7002	55
35	.7002	.7054	.7107	.7159	.7212	.7265	54
36	.7265	.7319	.7373	.7427	.7481	.7536	53
37	.7536	.7590	.7646	.7701	.7757	.7813	52
38	.7813	.7869	.7926	.7983	.8040	.8098	51
39	.8098	.8156	.8214	.8273	.8332	.8391	50
40	.8391	.8451	.8511	.8571	.8632	.8693	49
41	.8693	.8754	.8816	.8878	.8941	.9004	48
42	.9004	.9067	.9131	.9195	.9260	.9325	47
43	.9325	.9391	.9457	.9523	.9590	.9657	46
44	.9657	.9725	.9793	.9861	.9930	1.000	45
45	1.000	1.007	1.014	1.021	1.028	1.035	44
	60′	48′	36′	24′	12′	0′	ANG.
						COT	

	TAN						
ANG.	0′	12′	24′	36′	48′	60′	
46	1.036	1.043	1.050	1.058	1.065	1.072	43
47	1.072	1.080	1.088	1.095	1.103	1.111	42
48	1.111	1.118	1.126	1.134	1.142	1.150	41
49	1.150	1.159	1.167	1.175	1.183	1.192	40
50	1.192	1.200	1.209	1.217	1.226	1.235	39
51	1.235	1.244	1.253	1.262	1.271	1.280	38
52	1.280	1.289	1.299	1.308	1.318	1.327	37
53	1.327	1.337	1.347	1.356	1.366	1.376	36
54	1.376	1.387	1.397	1.407	1.418	1.428	35
55	1.428	1.439	1.450	1.461	1.472	1.483	34
56	1.483	1.494	1.505	1.517	1.528	1.540	33
57	1.540	1.552	1.564	1.576	1.588	1.600	32
58	1.600	1.613	1.626	1.638	1.651	1.664	31
59	1.664	1.678	1.691	1.705	1.718	1.732	30
60	1.732	1.746	1.760	1.775	1.789	1.804	29
61	1.804	1.819	1.834	1.850	1.865	1.881	28
62	1.881	1.897	1.913	1.929	1.946	1.963	27
63	1.963	1.980	1.997	2.015	2.032	2.050	26
64	2.050	2.069	2.087	2.106	2.125	2.145	25
65	2.145	2.164	2.184	2.205	2.225	2.246	24
66	2.246	2.267	2.289	2.311	2.333	2.356	23
67	2.356	2.379	2.402	2.426	2.450	2.475	22
68	2.475	2.500	2.526	2.552	2.578	2.605	21
69	2.605	2.633	2.661	2.689	2.718	2.748	20
70	2.748	2.778	2.808	2.840	2.872	2.904	19
71	2.904	2.938	2.971	3.006	3.042	3.078	18
72	3.078	3.115	3.152	3.191	3.230	3.271	17
73	3.271	3.312	3.354	3.398	3.442	3.487	16
74	3.487	3.534	3.582	3.630	3.681	3.732	15
75	3.732	3.785	3.839	3.895	3.952	4.011	14
76	4.011	4.071	4.134	4.198	4.264	4.332	13
77	4.332	4.402	4.474	4.548	4.625	4.705	12
78	4.705	4.787	4.872	4.959	5.050	5.145	11
79	5.145	5.242	5.344	5.449	5.558	5.671	10
80	5.671	5.789	5.912	6.041	6.174	6.314	9
81	6.314	6.460	6.612	6.772	6.940	7.115	8
82	7.115	7.300	7.495	7.700	7.916	8.144	7
83	8.144	8.386	8.643	8.915	9.205	9.514	6
84	9.514	9.845	10.20	10.58	10.99	11.43	5
85	11.43	11.91	12.43	13.00	13.62	14.30	4
86	14.30	15.06	15.89	16.83	17.89	19.08	3
87	19.08	20.45	22.02	23.86	26.03	28.64	2
88	28.64	31.82	35.80	40.92	47.74	57.29	1
89	57.29	71.62	95.49	143.2	286.5		0
90							
	60′	48′	36′	24′	12′	0′	ANG.
						COT	

Published and Copyright 1956 by The Welch Scientific Company, 7300 North Linder Avenue, Skokie, Illinois 60076

Catalog No. 592

APPENDIX E

OPERATION OF SPECTRONIC 20 FOR COLORIMETRY

1. Rotate the wavelength control until desired wavelength is indicated by the wavelength scale.

2. Turn on power switch, also called zero control, clockwise; the pilot light will glow. Allow five minute warm-up. With zero control bring meter needle to "0" on the Percent Transmittance scale of meter.

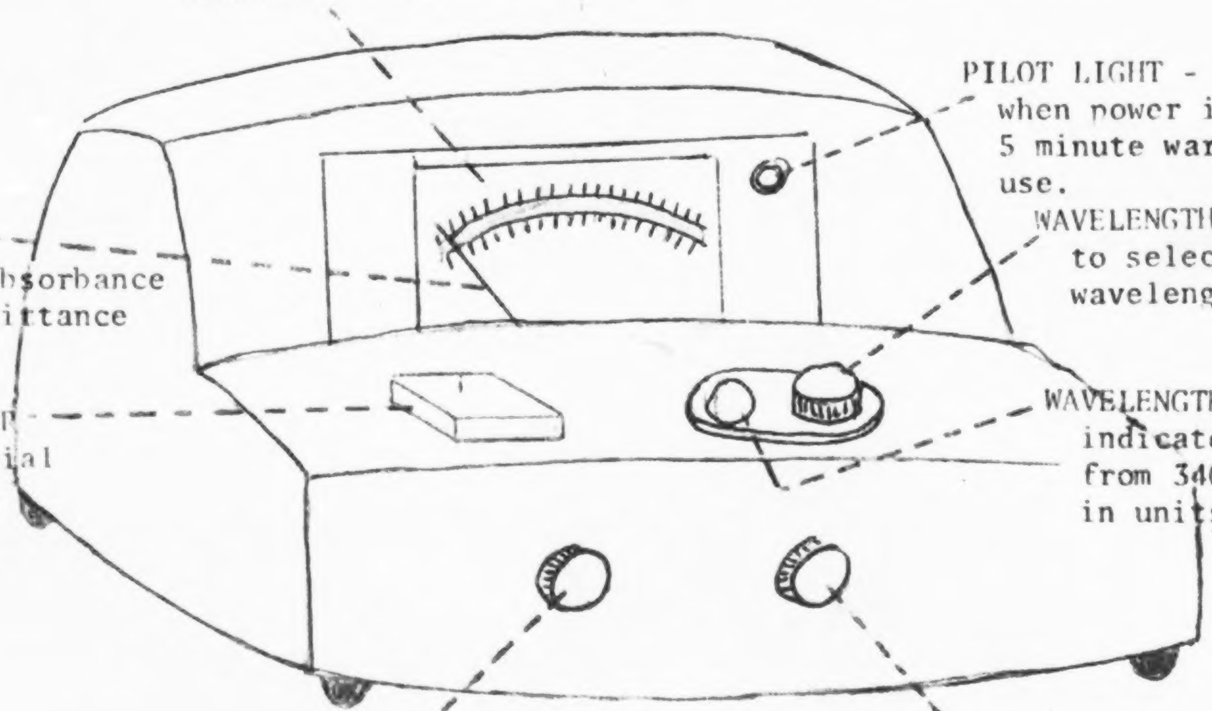
3. Insert test tube 1/2 full of distilled water into sample holder. Close adapter cover. Rotate Light Control until meter reads "100" on the Percent Transmittance scale.

4. Insert unknown sample in place of water or standard and read percent transmittance directly from meter.

5. It is best to turn the light control counterclockwise before changing to another wavelength.

IMPORTANT:

It is necessary to repeat step 3 each time a different wavelength is used. When operating on a fixed wavelength check periodically for meter "drift" from 100%.



METER SCALES:
Transmittance scale from 0 to 100% (black engravings at top)
Absorbance scale from 0 to infinity (red engravings at bottom)

PILOT LIGHT - glows red when power is on. Allow 5 minute warm-up before use.

WAVELENGTH CONTROL - to select desired wavelength.

METER NEEDLE - indicates absorbance &/or transmittance readings.

SAMPLE HOLDER - takes special test tube.

WAVELENGTH SCALE - indicates wavelengths from 340 to 960 mμ in units of 5 mμ

POWER SWITCH (ZERO CONTROL) turns on instrument and permits zeroing of meter needle on % transmittance scale.

LIGHT CONTROL - for setting meter needle to read 100% transmittance for the solvent being used.

APPENDIX F

LA PINE 203-92 PORTABLE BATTERY OPERATED pH METER

BATTERY CHECK

1. Set the temperature COMPENSATOR KNOB to BATTERY CHECK.
2. Turn the FUNCTION SWITCH to ON.
3. Turn the ASYMMETRY CONTROL KNOB until the black meter needle reads 7.
4. Turn the FUNCTION SWITCH back to BATTERY CHECK. As long as the black meter needle is on or to the right of the red battery check line on the meter scale panel the batteries are good. If the needle moves to the left of the battery check line replace one or the other or both dry cells and perform the battery check routine again until a good reading is obtained.

MOUNTING THE ELECTRODE

Position the electrode support arm by loosening the locking nut, moving the arm to the desired position, and tightening the nut. (When storing the pH meter loosen the nut and move the arm counterclockwise toward the electrode connection.)

Connect the combination electrode to the instrument by slipping the connector on the electrode lead over the connector on the case and turning it clockwise until it locks. To attach the electrode clamp slip it over the lead then slide it down over the upper (smaller diameter) plastic head of the electrode. Do not attempt to snap the electrode holder onto the electrode.

Keep the electrode filled with electrode filling solution to a point about 1/4" below the vent hole when the electrode is in a vertical position. To fill the electrode remove the vent plug and add electrode filling solution with the dropping pipet. Replace the vent plug until use.

STANDARDIZATION

When standardizing the pH meter use a buffer solution close to the pH of the sample, preferably within 2 pH units of the sample pH. The buffer solution should be at or near the temperature of the sample solution.

1. Turn the FUNCTION SWITCH to ON.
2. Set the temperature COMPENSATOR to the temperature of the buffer solution.

3. Open the vent hole on the electrode. The vent hole should always be open when the electrode is being used. Do not lose the rubber plug as it must be replaced when the electrode is not in use.

4. Rinse the end of the electrode with distilled water.

5. Immerse the electrode in the buffer solution.

6. Turn the FUNCTION SWITCH to READ.

7. Using the ASYMMETRY CONTROL set the black meter needle to the pH value of the buffer solution.

8. Turn the FUNCTION SWITCH back to ON.

9. The black meter needle will move off the value at which it was set by the asymmetry control. Set the red dead pointer to coincide with the black meter needle. As long as the pH metter is not turned OFF it will not be necessary to restandardize with the buffer solution. Simply set the function switch to ON and match the black meter needle to the red pointer using the asymmetry control.

10. Go to measurements procedure.

MEASUREMENT

pH MEASUREMENT

1. Clean the electrode with distilled water.

2. Immerse the electrode in the sample solution.

3. Turn the FUNCTION SWITCH to READ and read pH value. Then return to ON position when finished.

MILLIVOLT MEASUREMENT

1. The 203-95 platinum-calomel combination electrode must be used to make millivolt measurements. The 203-94 combination electrode furnished with the instrument is not suitable.

2. Clean the electrode with distilled water and immerse it in the sample solution.

3. Turn the temperature COMPENSATOR KNOB counterclockwise until it operates the snap switch and points to MILLIVOLTS.

4. Turn the FUNCTION SWITCH to ON.

5. Using the ASYMMETRY CONTROL set the black meter needle to read 0 millivolts.

6. Turn the FUNCTION SWITCH to READ and read millivolt value.

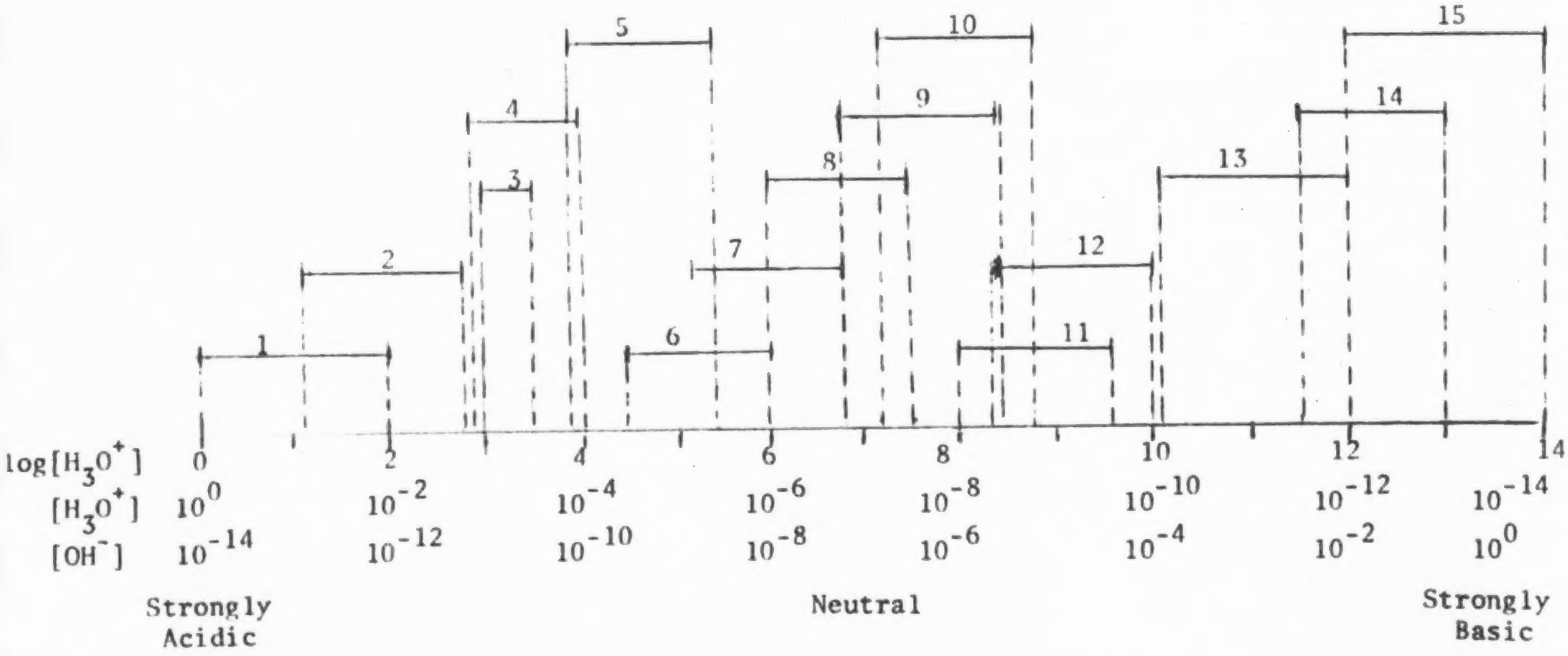
APPENDIX G

CENCO 021662 Electronic pH Meter

APPENDIX H

ACID - BASE INDICATORS

Diagram No.	Indicator	Color Change with Increasing pH	pH Range
1.	Methyl Violet		0 - 2.0
2.	Thymol Blue	red to yellow	1.2 - 2.8
3.	Bromphenol Blue	yellow to blue	3.0 - 3.6
4.	Methyl Orange	red to yellow	2.9 - 4.0
5.	Bromcresol Green	yellow to blue	3.8 - 5.4
6.	Methyl Red	red to yellow	4.4 - 6.0
7.	Bromphenol Red		5.2 - 6.8
8.	Bromthymol Blue	yellow to blue	6.0 - 7.6
9.	Phenol Red	yellow to red	6.8 - 8.4
10.	Cresol Red		7.2 - 8.8
11.	Thymol Blue		8.0 - 9.6
12.	Phenolphthalein	colorless to red	8.3 - 10.0
13.	Alazarin Yellow R.	yellow to violet	10.1 - 12.0
14.	Indigo Carmine	blue to yellow	11.6 - 13.0
15.	1, 3, 5 - Trinitrobenzene	colorless to orange	12.0 - 14.0



OPERATION OF THE OSTWALD VISCOSIMETER

DESCRIPTION:

Since viscosity is a measure of resistence to flow, the viscosity of a given fluid will be proportional to the time it takes the fluid to flow through a tube of sufficiently small diameter. Since viscosity varies directly with temperature, some provision must be made to keep the temperature of the fluid constant during the flow.

A U-shaped tube suspended vertically in a constant-temperature water-bath could serve as a primitive viscosimeter. By introducing a fluid into one of the arms, measuring the time it takes the fluid to reach the bottom of the tube and comparing this time to those for other fluids, one could obtain its relative viscosity. The Ostwald viscosimeter is a more refined version which permits us to determine what is known as the kinematic viscosity. By referring to the figure shown in this appendix, it can be seen that the Ostwald viscosimeter is a U-shaped tube which contains a section of capillary in one of its arms and the appropriate reservoirs for delivering and receiving a measured volume of fluid to and from the capillary.

The various dimensions of the Ostwald viscosimeter and their spacing relative to one another are such as to correct for a number of errors that otherwise would have to be taken into consideration in viscosity determinations. What the sources of these errors are and how the design of the viscosimeter corrects for them is quite complex. Here we shall only go into the theory governing its use.

THEORY:

Since we are dealing with a case of viscous flow through a capillary, Poiseuille's equation gives the quantity V, which flows through during time t:

$$V = \frac{\pi P R^4 t}{8 \eta L}$$

An expression for P, the pressure exerted by the liquid due to its weight is obtained as follows:

$$P = {}^{F}/_{A} = {}^{mg}/_{A}$$ where g is acceleration due to gravity acting on the column of liquid.

Substituting $D_m V$ for m:

$$P = \frac{D_m V g}{A}$$ where D_m = mass density

Substituting Ah for V and then cancelling the A's:

$$P = \frac{D_m Ahg}{A} = D_m hg$$

where h = the mean level difference of the liquid (variations in the level difference throughout the running happen to have no effect on the measurement.)

This value for P is now substituted into Poiseuille's equation:

$$V = \frac{\pi D_m hgR^4 t}{8 \eta L}$$

where g, R and L are constant
V is a fixed volume and **h** is calculated as the mean level difference.

Rearranging the latter so as to collect all constant values on one side, an expression can be obtained for what is defined as KINEMATIC VISCOSITY:

$$\eta / D_m = \left(\frac{\pi hgR^4}{8VL} \right) t$$

Since everything appearing in the brackets is constant:

$$\eta / D_m = kt$$

where k is in $cm^2/_{sec^2}$

$$\left(\frac{hgR^4}{VL} = \frac{cm}{cm^3} \cdot \frac{cm}{cm^2} \cdot \frac{cm^4}{cm} = cm^2/_{sec^2} \right)$$

Hence a measurement of the time of emptying the upper reservoir of the volume V, determines the kinematic viscosity η / D_m, once k is known.

The constant k can be established for a particular viscometer by measuring the flow-time of water or some other liquid of known viscosity and density:

$$k_{H_2O} = \eta /_{tD_m} = \frac{0.0089 \text{ poises}}{\text{t in secs} \cdot 1 \text{ gram}/_{cm^3}}$$

Then to obtain η:

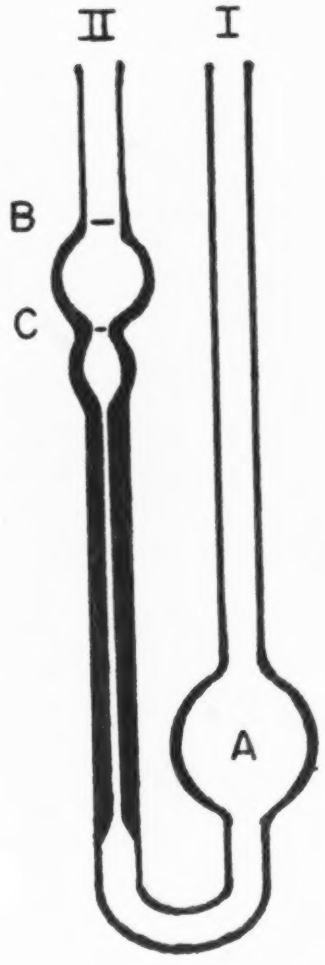
$$\eta = ktD_m$$

where η is in poises

$$\left(cm^2/_{sec^2} \cdot \frac{sec}{1} \cdot \frac{gram}{cm^3} = \frac{gram}{sec\text{-}cm} = poise \right)$$

PROCEDURE FOR DETERMINING VISCOSITIES:

The following procedure is run first with a volume of standard in order to determine k, and then with an equivalent volume of fluid whose viscosity is to be determined.



1. A volume of fluid is measured out in introduced through tube I to bulb A.

2. The viscosimeter with the sample inside is clamped vertically to a ringstand and immersed in a constant temperature water bath until the desired temperature is obtained.

3. The fluid is raised up into tube II by suction until the bottom of its upper meniscus is just on the B mark.

4. Removal of suction by releasing the index finger from tube I allows the fluid to begin its flow through the capillary and the time required for the meniscus to move from the B mark to the C mark is measured in seconds with a stop-watch.

5. The constant k is determined by measuring the time it takes for a given volume of standard to run through the capillary and then plugging this value into the following equation:

$$k = \frac{\eta_{H_2O \text{ at } 25^\circ C}}{tD_m}$$

The viscosity of an equivalent volume of unknown fluid is then given by:

$$\eta = ktD_m$$

TABLE OF VISCOSITY STANDARDS

Name of Substance	Mass Density	Viscosity in Centipoises at 25°C
Diethyl ether	0.71	0.22
Ethyl alcohol	0.79	1.20
H_2O	1.00	0.89
Ethylene glycol	1.12	14
Olive oil	0.92	67
Glycerol	1.26	950

The densities for aqueous solutions of sucrose, albumin and other substances are available in the HANDBOOK OF CHEMISTRY AND PHYSICS

APPENDIX J

Operation of Heathkit Oscilloscope

APPENDIX K

PREPARATION OF SOLUTIONS OF KNOWN CONCENTRATION IN TERMS OF MOLARITY OR NORMALITY

I. Concepts of Molarity, Normality and Equivalence

A. Molarity (M):

A 1-molar solution contains 1 gram-molecular weight of the dissolved substance per liter of solution.

$$\text{Molarity} = \frac{\text{moles of compound}}{\text{liters of solution}}$$

$$M \times V = \text{moles of compound}$$

Examples:

1M HCl = 36.5 g. HCl per liter of solution
1M H_2SO_4 = 98 g. H_2SO_4 per liter of solution
1M H_3PO_4 = 98 g. H_3PO_4 per liter of solution
1M NaOH = 40 g. NaOH per liter of solution

B. Normality (N):

A 1-normal solution contains 1 gram-equivalent weight of the dissolved substance per liter of solution.
A gram-equivalent weight of a substance is equal to the gram-molecular weight divided by the total valence of its positive or negative ions.

$$\text{Equivalent weight} = \frac{\text{M.W.}}{\#\text{ of + or - ions}}$$

$$\text{Normality} = \frac{\text{Equivalent weight}}{\text{liter of solution}} = \frac{\text{moles of + } \underline{\text{or}} \text{ - ions}}{\text{liter of solution}}$$

Thus: 1 Eq. Wt. of an acid is that weight which furnishes 1 mole of H_3O^+

1 Eq. Wt. of a base is that weight which furnishes 1 mole of OH^-

Examples:

$$1N\ HCl = \frac{\text{1 gram-molecular wt. HCl}}{\text{total valence of + or - ions}} \text{ per liter solution}$$

$$= \frac{36.5\ g/_{1H^+}}{\text{liter of solution}} = 36.5\ g\ ^{HCl/}{}_{\text{liter of solution}}$$

$$1N\ H_2SO_4 = \frac{98g/_{2H^+}}{\text{liter of solution}} = {}^{49gH_2SO_4/}{}_{\text{liter of solution}}$$

$$1N\ H_3PO_4 = \frac{98g/_{3H^+}}{\text{liter of solution}} = 32.7\ g\ ^{H_3PO_4/}{}_{\text{liter of solution}}$$

C. Milliequivalence (mE)

1 mE = 1/1000 of an equivalent weight

Example: 1N HCl contains 1 Equivalent weight per liter of solution

it contains 1 mE of H_3O^+ per ml. of solution.

Hence, adding 0.05 ml of 1N HCl to some other solution introduces 0.05 mE of H_3O^+ into that solution.

When doing titrations, it is important to know how many mE's (Equivalents) you are adding whenever you add a given volume of H_3O^+ or OH^- solution to the solution you are titrating.

II. The Preparation of Dilute Solutions of Known Concentration from Concentrated Stock Reagents.

A. Molar concentrations of some standard stock reagents

conc. HNO_3 = 15.4 M
conc. HCl = 11.6 M
conc. H_2SO_4 = 17.8 M
conc. CH_3COOH = 17.4 M

For preparing dilute solutions of concentrated reagents other than those listed above, consult The Handbook of Chemistry and Physics, pp. 1643-1663.

B. CAUTION WHEN USING CONCENTRATED REAGENTS:

When preparing these dilutions from concentrated reagents, do not add water to the concentrated acid or base. A small amount of acid at a time must be added carefully and slowly to a larger quantity of water to avoid violent bubbling and spattering. After all the acid has been added, the solution can be brought up to the desired volume by addition of more water

C. Examples:

1. To prepare 1000 ml of 3M HCl from conc. (11.6m) HCl, the required volume of concentrated HCl to be diluted to 1000 ml of solution is determined as follows:

$$\frac{11.6 \text{ moles HCl}}{1000 \text{ ml conc. HCl}} = \frac{3 \text{ moles HCl}}{x \text{ ml conc. HCl}}$$

$$11.6x = 3000; \quad x = 258 \text{ ml of conc. HCl}$$

Thus 258 ml of conc. HCl is to be diluted to 1000 ml of solution to get 3M HCl.

2. To prepare 1000 ml of 1M HCl from conc. reagent, it is necessary to dilute 86.2 ml of 11.6M HCl to 1000 ml of solution.

3. To prepare 0.1M HCl from 1M HCl, 100 ml of 1M HCl must be diluted to a 1000 ml solution.

In many cases, a full liter may not be required. Use only the required amount diluted to the desired volume to obtain a solution of the desired molarity.

III. Preparation of Dilute Solutions of Known Concentration from 1-Molar solutions:

A. General Formula for the number of millliters of 1M solution required to make up a liter of dilute solution of desired molarity:

ml of 1M solution = 1000 x desired molarity

Example:

ml of 1M HCl needed to make 1 liter of 0.01M HCl

= 1000 x .01 = 10ml of 1MHCl

thus, 10 ml of 1M HCl is diluted to a 1000 ml solution to get 0.01M HCl

B. General Formula for the number of milliliters of 1M solution required to make up a liter of dilute solution of desired normality:

$$\text{ml of 1M solution} = 1000 \times \frac{\text{desired normality}}{\text{total number of positive or neg. ions}}$$

Example:

ml of 1M H_2SO_4 needed to make 1 liter of 0.2N H_2SO_4

$$= 1000 \times \frac{0.2}{2} = 100 \text{ ml of 1M } H_2SO_4$$

thus, 100 ml of 1M H_2SO_4 is diluted to 1000 ml. of solution to give 0.2N H_2SO_4

C. To make up 1 liter of HCl, H_2SO_4, NaOH, NaCl, Na_2HPO_4, $Ca(OH)_2$ or KH_2PO_4 of specified M or N from 1 molar solutions of each of these substances, use the specified volumes from the table below and dilute to 1 liter with distilled water:

Specified M or N	VOL. of 1M SOLUTION REQUIRED (Milliliters)		
	HCl NaOH NaCl	H_2SO_4 $Ca(OH)_2$	Na_2HPO_4 KH_2PO_4
0.5M	500	500	500
0.2M	200	200	200
0.1M	100	100	100
0.01M	10	10	10
0.5N	500	250	167
0.2N	200	100	67
0.1N	100	50	33
0.01N	10	5	3

APPENDIX L

Preparation of Buffer Solutions

pH	ml. 0.2 Molar Na_2HPO_4	ml. 0.1 Molar Citric Acid
2.2	0.20	9.80
2.4	0.62	9.38
2.6	1.09	8.91
2.8	1.58	8.42
3.0	2.05	7.95
3.2	2.47	7.53
3.4	2.85	7.15
3.6	3.22	6.78
3.8	3.55	6.45
4.0	3.85	6.15
4.2	4.14	5.86
4.4	4.41	5.59
4.6	4.67	5.33
4.8	4.93	5.07
5.0	5.15	4.85
5.2	5.36	4.64
5.4	5.58	4.42
5.6	5.80	4.20
5.8	6.05	3.95
6.0	6.31	3.69
6.2	6.61	3.39
6.4	6.92	3.08
6.6	7.27	2.73
6.8	7.72	2.28
7.0	8.24	1.76
7.2	8.69	1.31
7.4	9.08	0.92
7.6	9.37	0.63
7.8	9.57	0.43
8.0	9.72	0.28

PROCEDURES FOR OBTAINING TITRATION CURVES

(from an article by Robert Cullen and
Paul Malcskey, William Allen High School
Allentown, Pa.)

TITRATION CURVES:

Data collected using a pH meter can be used to plot titration curves. These curves can be used to illustrate equivalence points, end points, and selection of indicators for manual titrations. Titrations can also be performed using a pH meter in lieu of an indicator.

For the collection of pH data of a sodium hydroxide-hydrochloric acid system titration, you need the following apparatus: pH meter with glass and calomel electrodes; magnetic or overhead stirrer; 50 ml buret (an offset delivery tip is convenient, but not necessary.)

Reagents: 0.10M sodium hydroxide solution (if stoichiometric calculations are desired, this solution should be standardized, using potassium phthalate); 0.10M hydrochloric acid; and buffer solution, pH = 7.00.

PROCEDURE:

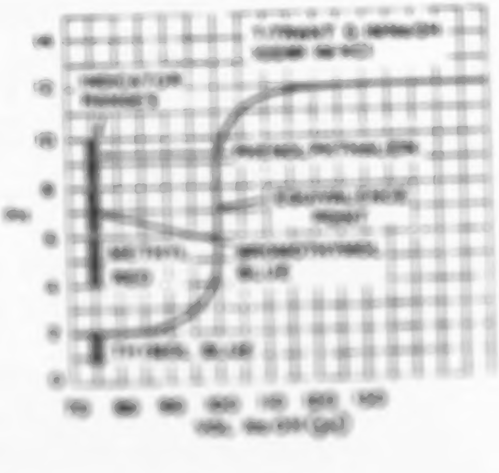
Standardize the pH meter with a small amount of pH = 7.00 buffer solution, according to directions given with the instrument. Using a pipet, transfer exactly 100 ml of 0.10M HCl solution to a 400 ml beaker. Insert the electrodes in the solution so that there is no danger of contact with the stirrer or beaker.

Rinse and fill a 50 ml buret with 0.10M NaOH solution. Adjust the meniscus so that it is at or below the zero mark on the buret. To facilitate calculations, it is convenient to add the titrant in whole number increments. Record and read the buret and pH readings.

Add 10.0 ml increments, wait about 20 seconds for pH to become constant, then read and record the buret and pH readings. At 90 ml, add 1.0 increments. At 98 ml, add 0.5 ml increments, and at 99 ml add 0.1 ml increments. The increments of NaOH to be added may be increased as the titration progresses farther beyond 100 ml. Continue to add NaOH until the pH is approximately 12 and remains relatively constant.

Plot pH on the vertical axis versus volume of NaOH on the horizontal axis, and draw a smooth curve through the experimental points. (See Fig. 1)

Figure 1.



The equivalence point is the point of greatest range of change of pH with addition of a reagent. As shown in Fig. 1, the equivalence point of the NaOH-HCl system will occur at about pH 7. Since the equivalence point corresponds to the inflection point of the graph (the point where the line curvature changes from concave up to concave down, or vice versa), it may be approximated visually.

NOTE: If stoichiometric relationships are desired, the concentration of the HCl solution may be calculated by equation:

Since $N = \frac{\#\text{eq.}}{\#\text{liters}}$, then

$$N_{acid} \cdot V_{acid} = N_{base} \cdot V_{base}$$

The end point is designated as that point in a titration where an indicator undergoes a visible color change. For stoichiometric use, the end point should coincide with the equivalence point. This relationship can be insured by the proper selection of indicators, as follows:

When the pH range over which an indicator undergoes its color change coincides with a portion of the flat vertical section of the titration curve, it will be a suitable indicator for the titration. To illustrate, the approximate pH ranges of color change of some indicators have been indicated on Fig. 1. Thus it can be seen that phenolphthalein, bromothymol blue, or methyl red would be a suitable indicator. Thymol blue would not be suitable for the NaOH-HCl system.

By conventional methods, a chemical indicator is used in a neutralization titration, and its change of color marks an end point. This should coincide with the equivalence point. Since the latter point can be determined from a titration curve, a titration may be performed (and the corresponding stoichiometric relationships determined) using a pH meter in lieu of an indicator.

DOUBLE INDICATOR TITRATIONS:

Double indicator titrations and selection of indicators can be illustrated with the sodium carbonate-hydrochloric acid system. 1.0 gr of Na_2CO_3 in 100 ml of solution titrated with 0.10 HCl illustrates the two-equivalent point curve.

(See

Figure 2

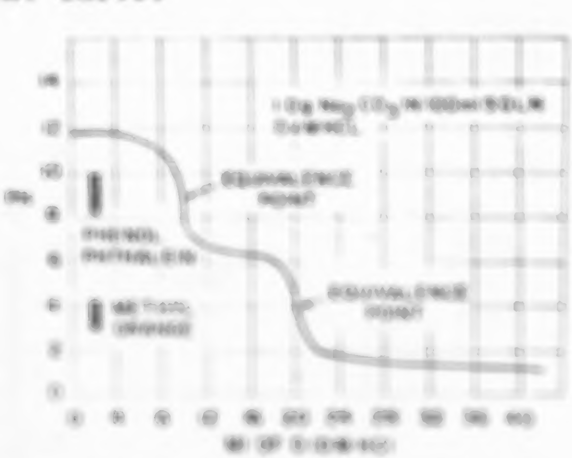
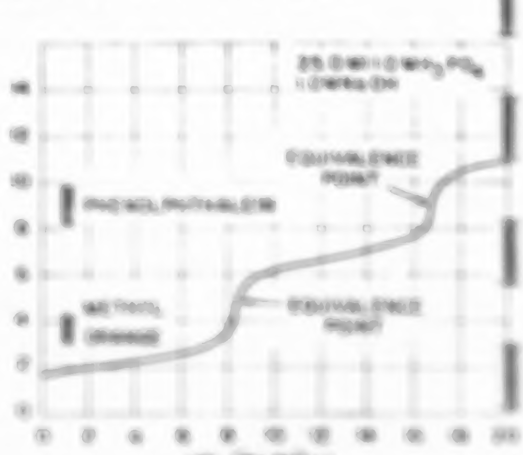


Figure 3



Phenolphthalein would be a good indicator for the first end point and methyl orange would work well for the second end point. Phosphoric acid titrated with NaOH would also illustrate a polyprotic system (See Fig. 3).

TABLE OF CONJUGATE ACID-BASE PAIRS

INCLUDING ACID IONIZATION CONSTANTS

DECREASING ACID STRENGTH

INCREASING BASE STRENGTH

CONJUGATE ACID		CONJUGATE BASE		K_{Acid}
NAME	FORMULA	FORMULA	NAME	
perchloric acid	$HClO_4$	ClO_4^-	perchlorate ion	large (K_A 1)
sulfuric acid	H_2SO_4	HSO_4^-	hydrogen sulfate ion	"
hydrogen chloride	HCl	Cl^-	chloride ion	"
nitric acid	HNO_3	NO_3^-	nitrate ion	"
hydronium ion	H_3O^+	H_2O	water	1
oxalic acid	HOOCCOOH	$HOOCCOO^-$	oxalate ion	5.9×10^{-2}
sulfurous acid	H_2SO_3	HSO_3^-	bisulfite ion	1.7×10^{-2}
hydrogen sulfate ion	HSO_4^-	$SO_4^=$	sulfate ion	1.2×10^{-2}
phosphoric acid	H_3PO_4	$H_2PO_4^-$	dihydrogen phosphate ion	7.5×10^{-3}
hydrogen fluoride	HF	F^-	fluoride ion	6.7×10^{-4}
nitrous acid	HNO_2	NO_2^-	nitrous ion	5.1×10^{-4}
acetic acid	CH_3COOH	CH_3COO^-	acetate ion	1.8×10^{-5}
hexaaquoaluminium III ion	$Al(H_2O)_6^{+++}$	$AL(H_2O)_5OH^{++}$	hydroxyopentaaquaaluminium III ion	
carbonic acid	H_2CO_3	HCO_3^-	bicarbonate ion	4.3×10^{-7}
hydrogen sulfide	H_2S	HS^-	hydrosulfide ion	1.0×10^{-7}
dihydrogenphosphate ion	$H_2PO_4^-$	$HPO_4^=$	biphosphate ion	6.3×10^{-8}
bisulfite ion	HSO_3^-	$SO_3^=$	sulfite ion	6.2×10^{-8}
ammonium ion	NH_4^+	NH_3	ammonia	5.7×10^{-10}
hydrogen cyanide	HCN	CN^-	cyanide ion	
bicarbonate ion	HCO_3^-	$CO_3^=$	carbonate ion	5.6×10^{-11}
biphosphate ion	$HPO_4^=$	$PO_4^{\equiv}$	phosphate ion	4.4×10^{-13}
phenol	C_6H_5OH	$C_6H_5O^-$	phenoxide ion	
hydrosulfide ion	HS^-	$S^=$	sulfide ion	1.3×10^{-13}

DECREASING ACID STRENGTH

INCREASING BASE STRENGTH

water	H_2O	OH^-	hydroxide ion	1.0×10^{-14}
ethyl alcohol	C_2H_5OH	$C_2H_5O^-$	ethoxide ion	K_A K_{H_2O}
ammonia	NH_3	NH_2^-	amide ion	"
methylamine	CH_3NH_2	CH_3NH^-	methylamide ion	"
hydrogen	H_2	H^-	hydride ion	"
methane	CH_4	CH_3^-	methide ion	"

HEATS OF COMBUSTION OF SOME COMMON ORGANIC COMPOUNDS IN CALORIES PER MOLE

Stearic Acid	2,711,000
Sucrose	1,349,000
Glucose	673,000
Ethyl Alcohol	327,000
Lactic Acid	326,000
Acetaldehyde	279,000
Pyruvic Acid	279,000

APPENDIX F

PHYSICAL QUANTITIES AND UNITS

Physical Quantity	Symbol	Definition	F. P. S.	C. G. S.	M. K. S.
Length	d, h l, s,	undefined	foot	centimeter	meter
Mass	m	undefined	slug	gram	kilogram
Time	t	undefined	second	second	second
Temperature	T	undefined	°F	°C	°C
Mag. Pole Strength	m	undefined		unit pole	weber
Electric Charge	q, Q	undefined			coulomb
Area	A	$A = l^2$	foot^2	centimeter^2	meter^2
Volume	V	$V = l^3$	foot^3	centimeter^3	meter^3
Force	F	$F = ma$	$\frac{\text{slug-ft}}{\text{sec}^2} = \text{lb}$	$\frac{\text{g-cm}}{\text{sec}^2} = \text{dyne}$	$\frac{\text{kg-m}}{\text{sec}^2} = \text{newton}$
Work	W	$W = Fd$	ft-lb	dyne-cm = erg	newton-meter = joule
Energy	E	$E = W$ stored work	ft-lb	dyne-cm = erg	newton-meter = joule
Power	P	$P = \frac{W}{t}$	$550\ \frac{\text{ft-lb}}{\text{sec}} =$ 1 horsepower	$\frac{\text{erg}}{\text{sec}}$	$\frac{\text{joule}}{\text{sec}} = \text{watt}$
Mag. Field Strength	H	$H = \frac{F}{m}$		Oersted	weber/meter^2
Velocity	V	$V = l/t$	foot/sec	cm/sec	meter/sec
Acceleration	a	$a = \frac{V}{t} = \frac{L}{t^2}$	foot/sec^2	cm/sec^2	meter/sec^2
Weight Density	D_w	$D_w = \frac{W}{V}$	lb/ft^3	dyne/cm^3	newton/meter^3
Mass Density	D_m	$D_m = \frac{m}{V}$	slug/ft^3	gram/cm^3	Kg/ meter^3
Pressure	P	$P = \frac{F}{A}$	lb/ft^2	dynes/cm^2	newtons/meter^2
Torque	T	$T = Fd$	lb-ft	dyne-cm	newton-meter
Impulse	I	$I = Ft$	lb-sec	dyne-sec	newton-sec
Momentum	p, M	$p = mv$	slug-ft/ sec	g-cm/sec	kg-m/sec

Physical Quantity	Symbol	Definition	F. P. S.	C. G. S.	M. K. S.
Frequency	f	$f = \frac{no.}{t}$	number/sec	number/sec	number/sec
Potential Difference	V	$V = \frac{W}{q}$			volt
Amperage	I,i	$I = \frac{q}{t}$			ampere
Resistance	R	$R = \frac{V}{I}$			ohms
Electric Field Strength	E	$E = \frac{F}{q}$			volt/meter

APPENDIX R

Length (continued)

1 mile = 1.609×10^3 meters
1.609 kilometers
1 parsec = 3.0837×10^{16} meters

Magnetism

1 gauss = 1.00×10^{-4} tesla
1.00×10^{-4} weber/meter^2
1 maxwell = 1.00×10^{-8} weber (Wb)
1 unit pole = 1.257×10^{-7} weber
1 weber = 1.00×10^8 maxwell

Mass

1 kilogram = 6.852×10^{-2} slug
1 metric ton = 1.00×10^3 kilograms
1 slug = 1.4594×10^1 kilogram
(1 slug weighs 32.17 pounds)
1 unified atomic mass unit = 1.660×10^{-27} kilogram

Mass-Energy

1 joule = 1.113×10^{-27} kilogram
6.705×10^9 u
1 kilogram = 6.0225×10^{26} u
8.987×10^{16} joules
1 unified atomic mass unit = 1.492×10^{-10} joule

Power

1 horsepower = 550 foot·lbf/second
7.457×10^2 watts
7.457×10^{-1} kilowatt
1.782×10^{-1} kilocalorie/second
1 kilowatt = 3.413×10^3 Btu/hour
1.341 horsepower

Power (continued)

1 watt = 1 joule/second
1×10^7 ergs/second

Pressure

1 atmosphere = 1.01325×10^5 newtons/meter^2
760 mm Hg (0°C)
760 torrs
1 millimeter of mercury (0°C) = 1.333×10^2 newtons/meter^2
1.934×10^{-2} psi (lbf/inch^2)
1 torr
1 torr = 1 mm Hg (0°C)

Time

1 day (ephemeris) = 1,440 minutes
8.64×10^4 seconds
1 year = 365.242 days
8.766×10^3 hours
5.259×10^5 minutes
3.1536×10^7 seconds

Volume

1 foot^3 = 2.8317×10^{-2} meter^3
1 gallon (U.S. liquid) = 3.7854 liter
3.7854×10^{-3} meter^3
1 liter = 1.00×10^{-3} meter^3
1×10^3 centimeters^3
1×10^3 milliliters
1.0567 quarts (U.S. liquid)
1 quart (U.S. liquid) = 9.463×10^{-1} liter

PHYSICAL CONSTANTS

acceleration due to gravity (standard) g_n	9.80665 m/s^2
alpha particle mass	6.6442×10^{-27} kg
atmospheric pressure (normal), atm	1.01325×10^5 N/m^2
Avogadro constant, N_A	6.02252×10^{23}/mole
Boltzmann constant, k	1.38054×10^{-23} J/°K
calorie, thermochemical, cal$_{th}$	4.1840 J
calorie, International Steam Table, cal$_{IT}$	4.1868 J
Coulomb law constant, k	2.3063×10^{-28} N·m^2/(elem.ch.)^2 8.9876×10^9 N·m^2/C^2
electron rest mass, m_e	9.1091×10^{-31} kg 5.48597×10^{-4} u
elementary charge, e	1.60210×10^{-19} C
Faraday constant, F	9.64870×10^4 C/equivalent 2.3061×10^4 cal/volt/equivalent
gas constant, universal, R	0.082051 atm l/mole/°K 8.314×10^7 ergs/mole/°K 8.3143 J/mole/°K 1.987 cal/mole/°K
gas, normal volume, V_o (for perfect gas)	2.24136×10^{-2} m^3/mole 2.24136×10^1 l/mole
gravitational constant, G	6.670×10^{-11} N·m^2/kg^2 6.670×10^{-11} m^3/kg·s^2
inch, in	2.54×10^{-2} m
liter, l	1.00×10^{-3} m^3
molal boiling-point elevation constant for water	0.51°C
molal freezing-point depression constant for water	1.86°C
neutron rest mass, m_n	1.67482×10^{-27} kg 1.0086654 u
Planck constant, h	6.6256×10^{-34} J·s and 6.6256×10^{-27} erg-sec
proton rest mass, m_p	1.67252×10^{-27} kg 1.00727663 u
ratio of proton mass to electron mass	1836
Rydberg constant, R_∞	1.0973731×10^7/m
speed of light (in vacuum), c	2.997925×10^8 m/s
speed of sound (in air at 20°C)	3.44×10^2 m/s
unified atomic mass unit, u	1.660×10^{-27} kg
water, ice point	273.15°K 0.00°C
water, triple point	273.16°K 0.01°C

PERIODIC CHART

SHELLS

s

d

LIGHT METALS

TRANSITION

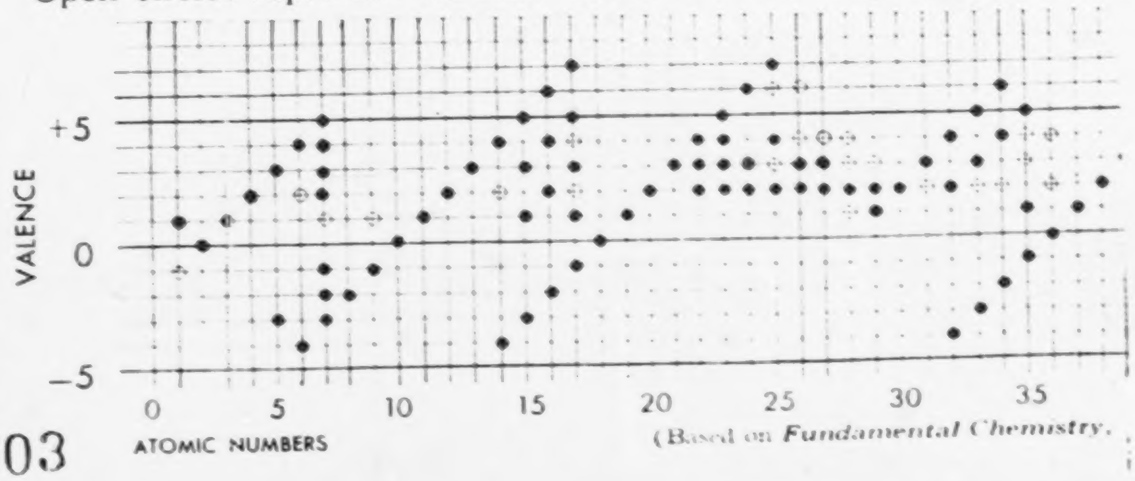
PRINCIPAL QUANTUM No. *n*	X-RAY NOTATION	I A	II A	III B	IV B	V B	VI B	VII B
1	K	1 1 H 1.00797						
2	L	2 1 3 Li 6.939	2 2 4 Be 9.0122					
3	M	2 8 1 11 Na 22.9898	2 8 2 12 Mg 24.312					
4	N	2 8 8 1 19 K 39.102	2 8 8 2 20 Ca 40.08	2 8 9 2 21 Sc 44.956	2 8 10 2 22 Ti 47.90	2 8 11 2 23 V 50.942	2 8 13 1 24 Cr 51.996	2 8 13 2 25 Mn 54.9380
5	O	2 8 18 8 1 37 Rb 85.47	2 8 18 8 2 38 Sr 87.62	2 8 18 9 2 39 Y 88.905	2 8 18 10 2 40 Zr 91.22	2 8 18 12 1 41 Nb 92.906	2 8 18 13 1 42 Mo 95.94	2 8 18 13 2 43 Tc (99)
6	P	2 8 18 18 8 1 55 Cs 132.905	2 8 18 18 8 2 56 Ba 137.34	57-71 See Lanthanide Series	2 8 18 32 10 2 72 Hf 178.49	2 8 18 32 11 2 73 Ta 180.948	2 8 18 32 12 2 74 W 183.85	2 8 18 32 13 2 75 Re 186.2
7	Q	2 8 18 32 18 8 1 87 Fr (223)	2 8 18 32 18 8 2 88 Ra 226	89-100 See Actinide Series				

6	P	LANTHANIDE SERIES (Rare Earth Elements)
7	Q	ACTINIDE SERIES

NOTE: A value given in parentheses denotes the mass number of the isotope of the longest known half-life, or of the best known one.

*The brackets are meant to indicate only the general order of subshell filling. The filling of subshells is not completely regular, as is emphasized by the use of red ink to denote shells which have electron populations different from the preceding element. In the case of He, subshell population is not by itself indicative of chemical behavior, and that element is therefore included in the inert gas group, even though helium possesses no p-electrons.

Open circles represent valence states of minor importance. or those



(Based on *Fundamental Chemistry*,

OF THE ELEMENTS

REVISED, 1964

ments of Merck & Co., Inc.

NG COMPLETED*

p

HEAVY METALS

NON METALS

INERT GASES

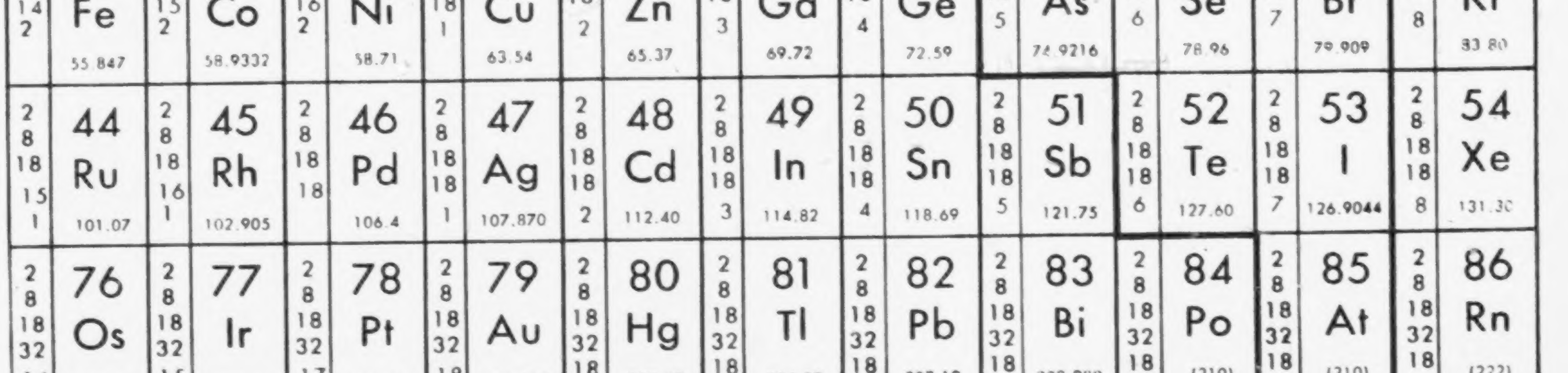
VIII	VIII	VIII	I B	II B	III A	IV A	V A	VI A	VII A	INERT GASES
										2 He 4.0026 2
					5 B 10.811 2 3	6 C 12.01115 2 4	7 N 14.0067 2 5	8 O 15.9994 2 6	9 F 18.9984 2 7	10 Ne 20.183 2 8
					13 Al 26.9815 2 8 3	14 Si 28.086 2 8 4	15 P 30.9738 2 8 5	16 S 32.064 2 8 6	17 Cl 35.453 2 8 7	18 Ar 39.948 2 8 8
26 Fe 55.847 2 8 14 2	27 Co 58.9332 2 8 15 2	28 Ni 58.71 2 8 16 2	29 Cu 63.54 2 8 18 1	30 Zn 65.37 2 8 18 2	31 Ga 69.72 2 8 18 3	32 Ge 72.59 2 8 18 4	33 As 74.9216 2 8 18 5	34 Se 78.96 2 8 18 6	35 Br 79.909 2 8 18 7	36 Kr 83.80 2 8 18 8
44 Ru 101.07 2 8 18 15 1	45 Rh 102.905 2 8 18 16 1	46 Pd 106.4 2 8 18 18	47 Ag 107.870 2 8 18 18 1	48 Cd 112.40 2 8 18 18 2	49 In 114.82 2 8 18 18 3	50 Sn 118.69 2 8 18 18 4	51 Sb 121.75 2 8 18 18 5	52 Te 127.60 2 8 18 18 6	53 I 126.9044 2 8 18 18 7	54 Xe 131.30 2 8 18 18 8
76 Os 190.2 2 8 18 32 14 2	77 Ir 192.2 2 8 18 32 15 2	78 Pt 195.09 2 8 18 32 17 1	79 Au 196.967 2 8 18 32 18 1	80 Hg 200.59 2 8 18 32 18 2	81 Tl 204.37 2 8 18 32 18 3	82 Pb 207.19 2 8 18 32 18 4	83 Bi 208.980 2 8 18 32 18 5	84 Po (210) 2 8 18 32 18 6	85 At (210) 2 8 18 32 18 7	86 Rn (222) 2 8 18 32 18 8

d

f

57 La 138.91 2 8 18 18 9 2	58 Ce 140.12 2 8 18 [illegible] 9 2	59 Pr 140.907 2 8 18 [illegible] 2	60 Nd 144.24 2 8 18 22 8 2	61 Pm (147) 2 8 18 23 8 2	62 Sm 150.35 2 8 18 24 8 2	63 Eu 151.96 2 8 18 25 8 2	64 Gd 157.25 2 8 18 25 9 2	65 Tb 158.924 2 8 18 26 9 2	66 Dy 162.50 2 8 18 28 8 2	67 Ho 164.930 2 8 18 29 8 2	68 Er 167.26 2 8 18 30 8 2	69 Tm 168.934 2 8 18 31 8 2	70 Yb 173.04 2 8 18 32 8 2	71 Lu 174.97 2 8 18 32 9 2
89 Ac (227) 2 8 18 32 18 9 2	90 Th 232.038 2 8 18 32 18 [illegible] 2	91 Pa (231) 2 8 18 32 20 9 2	92 U 238.03 2 8 18 32 21 9 2	93 Np (237) 2 8 18 32 22 9 2	94 Pu (244) 2 8 18 32 23 9 2	95 Am (243) 2 8 18 32 24 9 2	96 Cm (247) 2 8 18 32 25 9 2	97 Bk (247) 2 8 18 32 26 9 2	98 Cf (251) 2 8 18 32 27 9 2	99 Es (254) 2 8 18 32 28 9 2	100 Fm (253) 2 8 18 32 29 9 2	101 Md (256) 2 8 18 32 30 9 2	102 No (254)	103 Lw (257)

unobtainable in presence of water. For transuranian elements, all valences reported are listed.



nd Edition, by H. G. Deming, Published by John Wiley & Sons, Inc.)

ED0 53946

PA-24
BR-5-0646

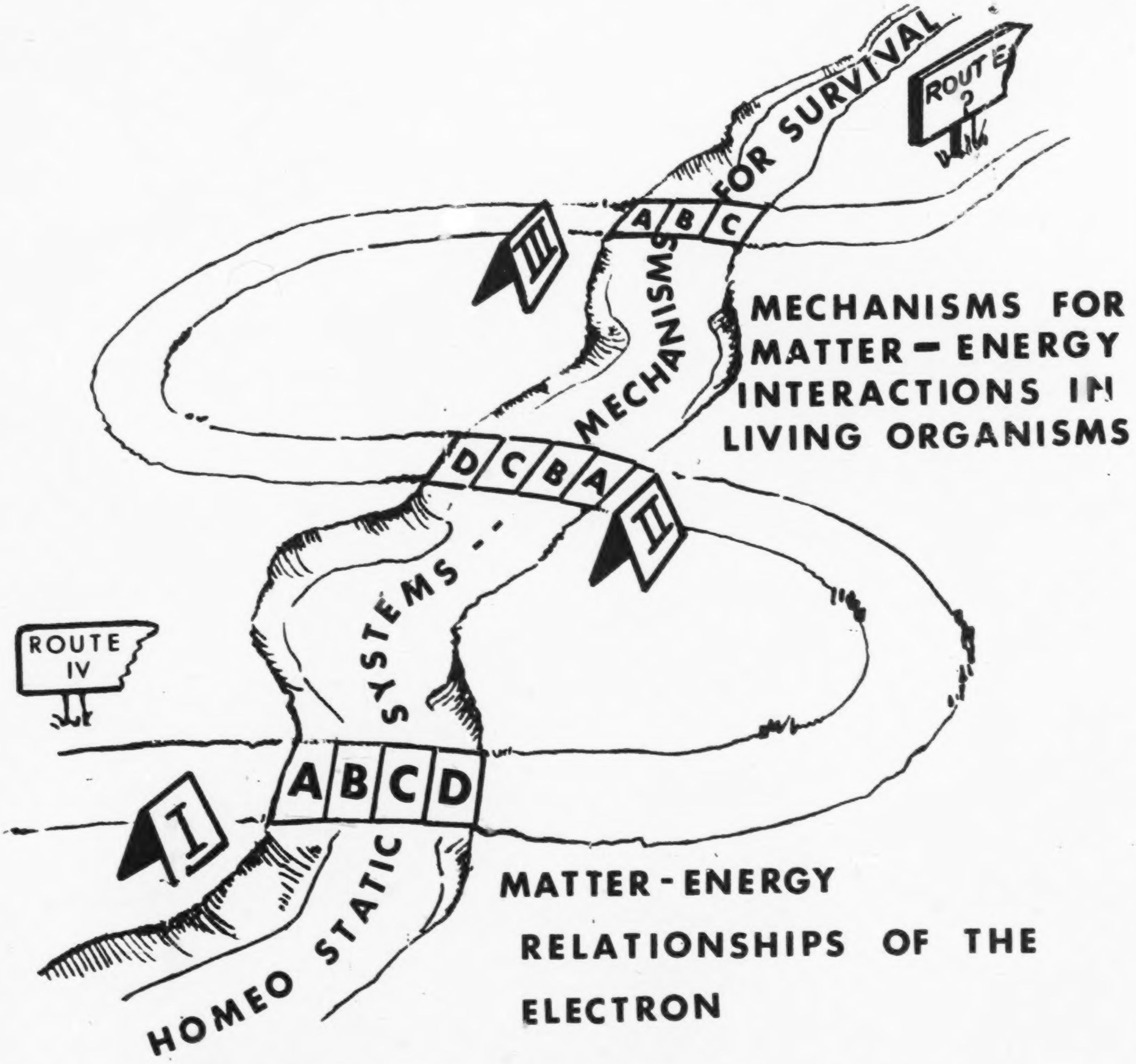
Carl H. Pfeiffer
Wisconsin State Department of Education

SCIENCE

[illegible]

SE 012 152

SCIENCE IV


ROUTE ?
HOMEO STATIC SYSTEMS -- MECHANISMS FOR SURVIVAL
A B C
III
MECHANISMS FOR MATTER — ENERGY INTERACTIONS IN LIVING ORGANISMS
D C B A
II
ROUTE IV
A B C D
I
MATTER - ENERGY RELATIONSHIPS OF THE ELECTRON

II. MECHANISMS FOR MATTER-ENERGY INTERACTIONS IN LIVING ORGANISMS

A. Mechanisms Associated with the Capture, Storage and Utilization of Energy and Matter

B. Mechanisms Associated with the Transport, Regulation and Exchange of Matter Throughout the Organism's Internal Environment

C. Mechanisms Associated with the Ability of Organisms to Act and React

D. Mechanisms by which Living Matter Maintains and Propogates its Orderliness Through Space and Time

MECHANISMS ASSOCIATED WITH THE TRANSPORT, REGULATION AND EXCHANGE OF MATTER THROUGHOUT THE ORGANISM'S INTERNAL ENVIRONMENT

Composition of Body Fluids
Functions of Body Fluids
Dynamics of Body Fluids

The material on this page may be found

TITLE Life Science, Intermediate Level

AUTHOR Milton S. Lesser

PUBLISHER AMSCO School Publications

PAGE NO. 102

AN OVERVIEW OF THE GENERAL RELATIONSHIPS BETWEEN SYSTEMS SPECIALIZED FOR THE TRANSPORT, REGULATION AND EXCHANGE OF OF MATTER THROUGHOUT THE ORGANISM'S INTERNAL ENVIRONMENT

In IIA we examined in some detail the structure and general functions of four very specialized systems within multicellular organisms: the digestive, the respiratory, the circulatory, and the excretory system. Of necessity each system was considered separately, but it is necessary to remember that these systems' functions are interdependent. Not one of these systems could survive in the absence of any other - they are interconnected in both their anatomy and their physiology. As you know, the digestive system is necessary for the intake of matter, which is then assimilated into the organism as a source of energy; but you must remember that this energy could never be released without a source of oxygen - this is where the respiratory system comes in. The oxygen is transported in turn by the circulatory system. After the cell's processes have released the stored energy of the food molecules by breaking them down the waste residue must be quickly removed or the resulting high concentration of toxic materials would poison the cells of the organism. The circulatory system again transports these wastes to a specialized group of organs, the excretory system, whose function it is to remove waste.

Another very important idea to be remembered is that all of these processes occur within cells, some very specialized, but all bearing an outer cell membrane. Perhaps the role that this membrane plays in transporting materials into and out of the cell will be more fully appreciated after the completion of this section of the course.

3

COMPOSITION OF BODY FLUIDS

INTRODUCTION:

One of the principal problems facing a cell as part of a multicellular organism is that it no longer has free access to the external environment. To obtain water, salts, and organic nutrients, to get rid of wastes, and for gas exchange, it must depend on some sort of circulatory system. The importance of the circulation in maintaining an animal can hardly be overestimated. By far the largest cause of death in man is failure of the circulation.

Beyond its nutritive and excretory roles, the circulatory system in vertebrates performs an essential function in defending the animal from invasions of foreign organisms and foreign molecules. A failure of these defense mechanisms can lead to death as surely as the failure in the nutritive and excretory functions of the blood.

The blood of higher animals is a complex tissue. It may be separated by centrifugation into a fraction composed of cells, and a cell-free liquid fraction called the plasma. The plasma is a complex solution of proteins, sugars, salts, and other substances. One of the plasma proteins, fibrinogen, is the precursor of the insoluble fibrin of the blood clot. The remainder of the plasma after the clot has been removed is called serum. For both the nutritive and defensive roles of the circulatory system, both cells and plasma are needed.

Let us first consider the nutritive function of the blood. Many substances are carried in water solution in the plasma and are transported to the cells in this fashion. Other substances are adsorbed on proteins in the blood and are carried in this way. Gas exchange presents further problems. A little oxygen and somewhat more carbon dioxide can be dissolved in the plasma; but the major transport of both these gases in vertebrates depends upon the red pigment, hemoglobin, an iron-porphyrin-protein. The hemoglobin is carried in specialized cells, the red blood cells or erythrocytes. About as much hemoglobin is packed into these cells as they can possibly hold. Some 30% of the red blood cell or 95% of its dry weight is hemoglobin. The red blood cells are nonmotile, and do little more than carry hemoglobin. In mammals these cells lose their nuclei before maturing; and as you would expect, from that point on they run down metabolically, dying after and average life of about 120 days.

Human red blood cells are about 7.5 microns in diameter and have a biconcave disc shape which facilitates gas exchange. They are present in great numbers in the blood; a normal young man may have nearly six million erythrocytes per cubic millimeter of blood. (If the human blood volume is 6 liters, how many new red blood cells must be produced per day to keep the total number constant?)

For defense, the body depends on both plasma proteins and cells. The plasma contains a special group of proteins, called antibodies, which combine with and hence inactivate foreign proteins, viruses, or polysaccharides, and also cause invading bacteria to clump together. Each antibody is specific for the substance or type of cell with which it reacts. Somehow our defense machinery knows the shapes of our own proteins and leaves them alone. When foreign proteins or polysaccharides called antigens are introduced into the circulation, antibodies against them are quickly synthesized.

The cells of the defense system, the white blood cells or leucocytes, in marked contrast to the red blood cells, are motile and highly active. They can travel about in the blood stream, or by going through the wall of a blood vessel can wander out into the tissues and tissue spaces. They move more or less as does an ameba, by flowing in one direction or another. When infection strikes, they quickly travel to the invasion site in great numbers. There they destroy large numbers of invading organisms by ingesting them, a process called phagocytosis, and also release special substances which help organize the defense. The pus formed in and around an infection consists of dead white blood cells.

A specialized group of white blood cells, the plasma cells (plasmocytes), produce antibodies. White blood cells can be divided into two groups: the round, smooth-nucleated lymphocytes and the granulocytes, which have irregularly lobes nuclei. White blood cells are slightly larger than red blood cells, and are present in considerably smaller number (about 8000 per cubic millimeter of blood). During infection, however, their number increases enormously, and this increase provides a sensitive warning that an infection is present.

A third group of elements in the blood, the platelets (thrombocytes), is involved in clotting. When a blood vessel is cut open, an interlacing network of fibrin forms a clot which eventually closes the wound. This process is complicated, involving the platelets, calcium ions, and the plasma proteins thrombin and fibrinogen (thrombin is a proteinase which activates fibrinogen by hydrolyzing off part of it, turning it into fibrin).

In addition to its nutritive and defensive activites, the blood provides a constant internal environment for the cells and tissues of the body. In a mammal the pH, temperature, and sugar concentration of the blood are held within very narrow limits. This relative stability of the internal environment makes it possible for a mammal to experience enormous changes in the extermal environment without damage. The great nineteenth century physiologist, Claude Bernard, was thinking of this when he said, "The constancy of the internal environment is the condition of a free life."

5

Reading: Allison, "Sickle Cells and Evolution", Scientific American, August, 1956 (#1065).

Burnet, "The Mechanism of Immunity", Scientific American, January, 1961 (#78).

Gordon, Blood Cell Physiology, BSCS Pamphlet

Nossal, "How Cells Make Antibodies", Scientific American, December, 1964 (#199)

Porter, "The Structure of Antibodies", Scientific American, October, 1967 (#1083)

Smidt-Neilsen, "Coagulation of Blood", Animal Physiology pp 25-26.

Speirs, "How Cells Attach Antigens", Scientific American, February 1964 (#176)

Wood, "White Blood Cells vs. Bacteria", Scientific American, February 1951

ZuckerKandl, "The Evolution of Hemoglobin", Scientific American, May 1965 (#1012)

COMPOSITION OF BODY FLUIDS

I. Macroparticle Fraction of Whole Blood

  A. Red Blood Cells or Erythrocytes

    1. Function - Gas Transport

      a. Respiratory Pigments

      b. Factors Affecting Gas Transport

        (1) Oxygen Dissociation Curve

        (2) Blood pH

    2. Origin and Life History of Erythrocytes

    3. Problems

      a. Anemia

      b. Polycythemia

B. White Blood Cells or Leucocytes

1. Function

a. Diapedesis

b. Phagocytosis

2. Origin and Life History of Leucocytes

3. Problems - Leukemia

C. Blood Platelets or Thrombocytes

1. Function - Clot Formation

2. Origin and Life History

3. Problems - Defective Clotting

II. Fluid Fraction of Whole Blood

A. Water

B. Inorganic Salts

C. Blood Sugar

D. Plasma Proteins

1. Antibodies

a. Formation

b. Function

2. Fibrinogen

3. Blood Types

E. Hormones

III. Interstitial Fluids

   A. Lymphatic System

      1. lymph

      2. lymph vessels

      3. lymph glands

   B. Function

IV. Control of Osmotic Balance Between Blood and Interstitial Fluids and Cell Fluids

10-12

The material on pages 10-12 may be found

TITLE Lab Investigations in Biology

AUTHOR Smallwood, W. L. and Green, E. R.

PUBLISHER Silver Burdett

PAGE NO. 119-122

Laboratory Investigation

EXAMINATION OF BLOOD CELLS

INTRODUCTION:

The circulatory system can be called the body's transportation system. Almost everything that must be transported from one part of the body to another is transported in the blood. Examples of substances that are transported in the blood are oxygen, carbon dioxide, absorbed foods, and hormones.

Blood is composed of different types of cells suspended in a fluid medium called plasma. The cells are very small. One cubic millimeter of blood may contain more than 5 million cells (solid particles).

The solid particles of the blood are the erythrocytes (red blood cells), leucocytes (white blood cells), and platelets. The erythrocytes contain hemoglobin and carry oxygen and carbon dioxide to and from the cells. Leucocytes ingest bacteria and other foreign substances. The platelets are essential to blood clotting.

Examination of blood cells and various chemical analyses of blood are important diagnostic tools. In order to carry out a microscopic examination of blood cells, the blood must be spread very thinly on a slide. In this investigation, you will become familiar with some of the techniques of preparing and staining blood smears.

PURPOSE:

To prepare and study a stained slide of blood cells.

MATERIALS:

- sterile lancets
- microslides
- rinsing jars
- compound microscope
- wax pencil
- cotton
- paper toweling
- alcohol
- Wright's stain
- buffer solution, pH 6.4
- distilled water

PROCEDURE:

A. Drawing the blood sample:

Swab the ball of your middle or index finger with 70% isopropyl.alcohol and then with your thumb apply pressure to the base of the terminal joint and push forward until the ball of the finger becomes reddened with the blood that you have forced into its capillaries.

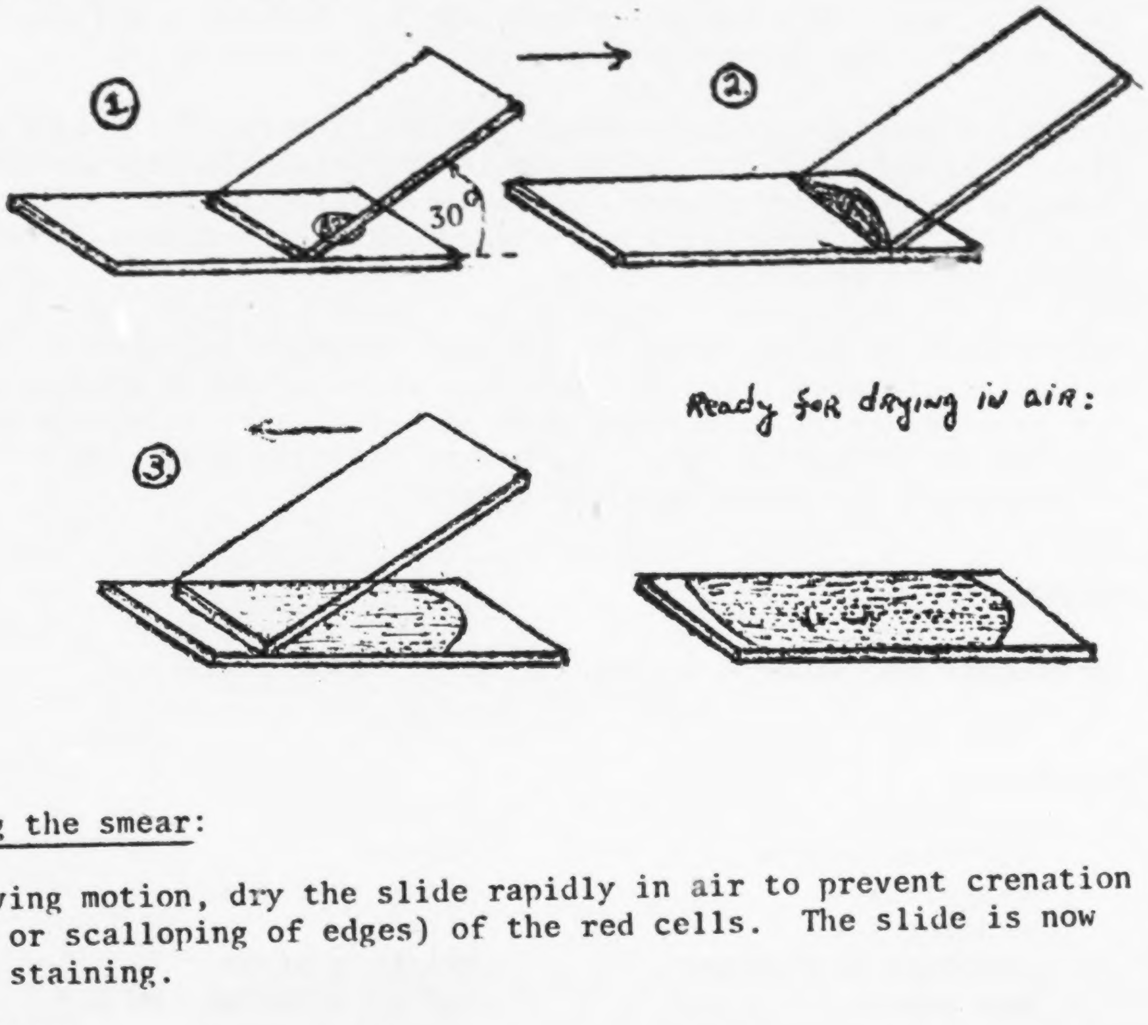
Now prick the skin quickly with a new sterile lancet, wiping away the first drop of blood. Squeeze out a second drop of blood touching it to the right end of a clean microscope slide about one centimeter from the edge.

B. Making the smear: (following steps illustrated below)

1. Place the narrow edge of another clean and nick-free slide to the left of the drop and at a 30° angle over it.

2. Keeping the angle, pull the slide carefully to the right until it touches the blood. Wait for the blood to spread along the line of contact.

3. Now with the right hand, push the angled slide smoothly toward the left until the blood is spread out or until the other end of the slide is reached. This method drags the blood along rather than pushes it which would crush some of the cells. The rate at which the blood is fed out can be varied by changing the angle of the slide. With thick blood reduce the angle to feed it out at a slower rate. If the blood is thin increase the angle.



C. Drying the smear:

With a waving motion, dry the slide rapidly in air to prevent crenation (notching or scalloping of edges) of the red cells. The slide is now ready for staining.

D. Staining:

1. With a wax pencil mark off a rectangular region 40mm in length and about the width of the slide on the side that has the smear. The wax lines will confine the staining solutions in this region to insure the best results.

2. Being careful that the stain does not spill over the wax marks, cover the blood-smear with 10 to 12 drops of Wright's Stain for 1 to 2 minutes. Avoid evaporation by cutting down on time or by adding more stain.

3. Add an equal amount of buffer solution (pH6.4) leaving on for 2 to 4 minutes.

4. Rinse off the stain and buffer mixture in distilled water with one or

two dips only. Avoid precipitate deposits by flushing with a pipette.

5. Blot the slide with two sheets of filter paper. Press but do not rub as this will remove some of the cells.

6. Allow the slide to dry thoroughly before mounting and observing.

E. Mounting:

If the slide is particularly good and permanency is desired, apply a drop or two of mounting medium (Kleermount) covering over with a 40mm cover-glass. Avoid bubbles. Label the slide with your name, the date, and the type of stain used.

Slides that have not been thoroughly dried above room temperature so as to remove all water will not be of any value when mounted in this manner.

OBSERVATIONS AND QUESTIONS:

When the slide is completely dry, examine the prepared blood smear under low power magnification. The red blood cells will appear to be pinkish after staining. Many of the larger white blood cells will appear to be blue, since they have large blue-stained nuclei.

1. Describe the observable differences between red and white blood cells in the stained preparation.

2. Using the 97X oil immersion objective and a Whipple micrometer disk inserted into the eyepiece, determine the diameters of the various cells in microns. Your instructor will have this equipment available for you.

3. There are five types of white blood cells that can be recognized by the way the cytoplasm stains and by the structure of the nucleus. Checking with Blood Cell Physiology, by Gordon, see if you can find and recognize the 5 types on your slide.

4. White blood cells are described as amoeboid. Explain this statement and relate it to their function.

5. Why is there a greater abundance of red cells than white cells?

6. What are some of the conditions that can cause an abnormally high number of leucocytes in the blood?

7. Design a method for determining the ratio of white blood cells to red blood cells and carry it out with your slide.

8. How does the ratio of wbc's to rbc's compare with those determined by other members of the class?

9. Can you find any evidence that the average ratio of wbc's to rbc's differs according to sex?

10. Why was a staining solution used in this investigation?

FURTHER INQUIRY:

Make smears of the blood of a frog, a fish, or any other animal available in the laboratory. What similarities do you notice between the blood cells of various animals? What differences in structure or proportion of blood cell types do you notice?

17-18

The material on pages 17, 18 may be found

TITLE Twenty-Six Afternoons for Biology

AUTHOR Wald, G., et al

PUBLISHER Addison-Wesley Publishing Company, Reading, Mass. 1966

PAGE NO. 92-93

Mechanisms Associated with the Transport, Regulation
and Exchange of Matter Throughout the Organism's
Internal Environment

FUNCTIONS OF BODY FLUIDS

Required Reading:

Part I	Carlson, Johnson and Covert, The Machinery of the Body pp 67-135 Chapman and Mitchell, "The Physiology of Exercise", Scientific American May 1965 Comroe, "The Lung" Scientific American Feb. 1966 (#1034) Langley, Homeostasis, Chapter 6 Schmidt-Neilsen, Animal Physiology pp 13-25 Telfer and Kennedy, Biology of Organisms pp 247-251
Part II	Baker, Matter, Energy and Life, Chapter 6 Vanderwerf, Acids, Bases and the Chemistry of the Covalent Bond Chapter 2 White, "Acids and Bases", Chemical Background for the Biological Sciences pp 29-59
Part III	Langley, Homeostasis, Chapters 4 and 7 Schmidt-Neilsen Animal Physiology Chapter 1 and 4 Telfer and Kennedy, The Biology of Organisms "The Kidney" pp 224-232, also p. 269 2nd paragraph
Part IV	Schmidt-Neilsen, Animal Physiology, begin with "The nervous system as originator of hormones" p. 6, p. 102-112. Langley, Homeostasis, Chapter 8 p. 28-29 (Ref. to Acetylcholine) Telfer and Kennedy, Biology of Organisms, "Homeostasis and Hormone Controls in Animals", pp 266-271
Part V	Langley, Homeostasis, Chapter 3

I. Gas Transport

A. Oxygen Transport

1. Hemoglobin

a. Structural Properties

(1) empirical formula

(2) structural formula

(3) functional parts of the molecule

(4) derivatives of hemoglobin and related compounds

b. Functional Properties

(1) redox mechanism

(2) absorption spectra for reduced and oxidized forms

2. Oxygen Supply and Demand

a. Respiratory demands

b. Supply

(1) oxygen carrying capacity of plasma alone

(2) Oxygen carrying capacity of whole blood

(3) Importance and distribution of hemoglobin

3. Factors Affecting Oxygen Transport

a. Hemoglobin Capacity vs. Amount Surrendered

(1) Full Load

(2) Amount Delivered to Cells in Capillary Bed

b. Solubility of Oxygen

(1) Solubility in Water

(2) Solubility as Affected by Temperature

(3) Solubility as Affected by Salinity

(4) Solubility Coefficients

TABLE I: SOLUBILITIES OF MAJOR GASES AT VARYING TEMPERATURES

	SOLUBILITY COEFFICIENTS		
Temperature °C	Carbon Dioxide	Oxygen	Nitrogen
0	1.713	0.0489	0.0235
5	1.424	0.0428	0.0209
10	1.194	0.0380	0.0186
15	1.019	0.0341	0.0168
20	0.878	0.0310	0.0154
25	0.759	0.0283	0.0143

TABLE II: SOLUBILITY COEFFICIENTS OF OXYGEN AS VARYING WITH TEMPERATURE AND CHLORINITY

	CHLORINITY IN GM/KGM			
Temperature °C	0	15	17	20
0	0.0489	0.0406	0.0395	0.0378
5	0.0429	0.0359	0.0350	0.0336
10	0.0380	0.0321	0.0313	0.0301
15	0.0342	0.0292	0.0284	0.0274
20	0.0310	0.0267	0.0262	0.0253
25	0.0283	0.0246	0.0240	0.0231

4. Calculating the Gaseous Content of a Liquid

a. Absorption Coefficient

b. Dalton's Law

(1) Total Pressure of Gaseous Mixture

(2) Proportion of each Gas Dissolved

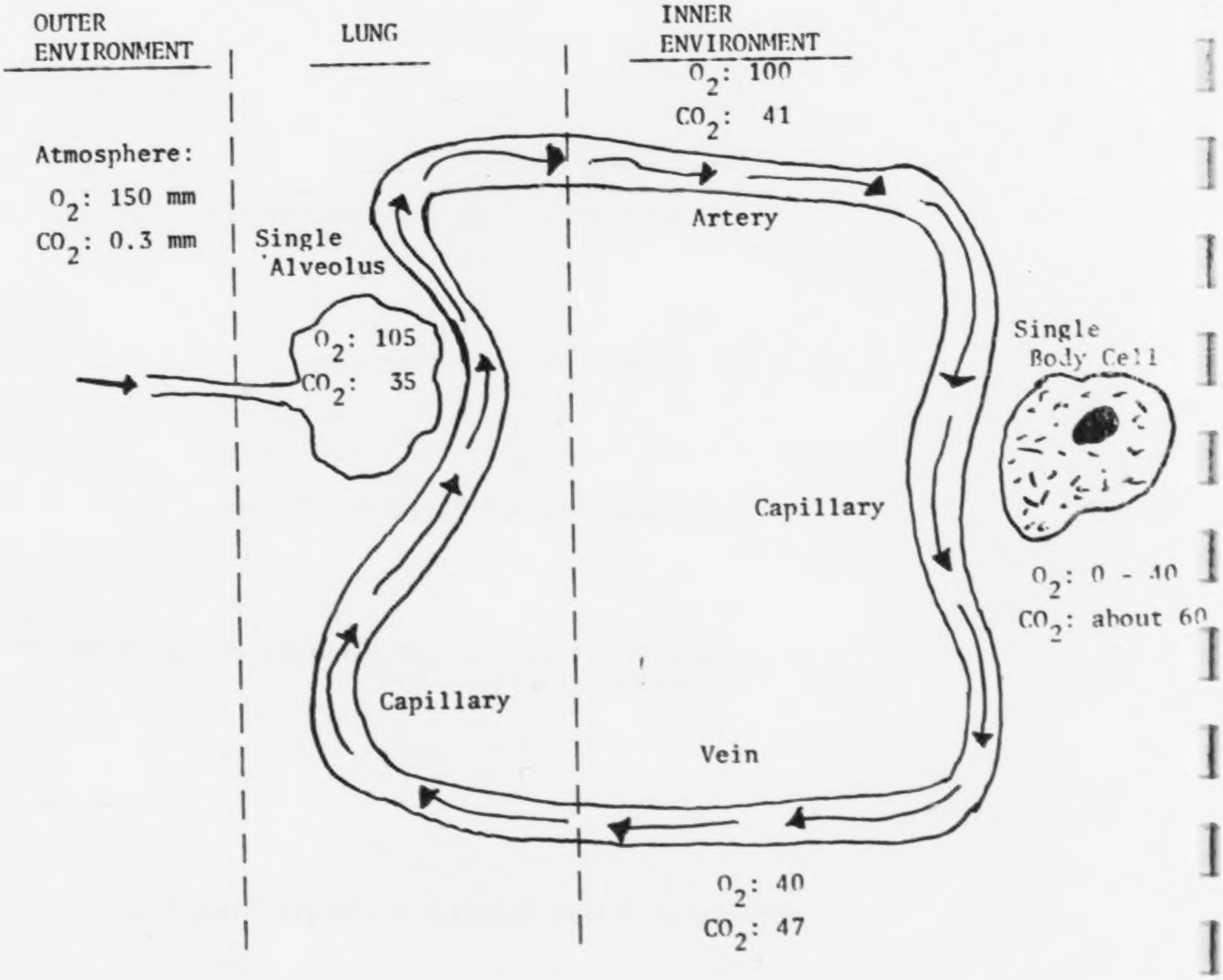
(3) Volume of Gas in Known Samples of Water

(4) Examples

5. Oxygen Tension

6. Oxygen Dissociation Curve
    a. Oxygen Dissociation
        (1) At High Pressure
        (2) At Low Pressure
    b. The Definite Proportion Rule
        (1) Saturation Point for Alveolar Air
        (2) Release at Lower Pressures
        (3) Oxygen Partial Pressures of Zero
    c. The Bohr Effect: Carbon Dioxides influence on the Oxygen Dissociation Curve

7. Effects of Carbon Monoxide on Oxygen Transport


OUTER ENVIRONMENT
LUNG
INNER ENVIRONMENT
O_2: 100
CO_2: 41
Atmosphere:
O_2: 150 mm
CO_2: 0.3 mm
Single Alveolus
O_2: 105
CO_2: 35
Artery
Single Body Cell
Capillary
O_2: 0 - 40
CO_2: about 60
Capillary
Vein
O_2: 40
CO_2: 47

OXYGEN - CARBON DIOXIDE EXCHANGE

B. Carbon Dioxide Transport

1. Carbon Dioxide Carrying Capacity of Whole Blood

   a. Total Capacity per 100 milliliters

   b. Amount Given Off by Lungs per 100 milliliters Blood

2. Form of Carbon Dioxide as Carried by Blood

   a. Sodium Bicarbonate

   b. Effects of High Carbon Dioxide on Hydrogen Ion Concentration

   c. Ionic Equilibrium

   d. Buffer System and its Relative Stability

C. Mechanism of Oxygen - Carbon Dioxide Exchange

1. Diffusion Gradient Responsible for:

   a. Oxygen Transfer from Lungs to Tissues

   b. Carbon Dioxide Transfer from Tissues to Lungs

   c. Constancy of Arterial Blood in Regard to Partial Pressures of Oxygen and Carbon Dioxide

   d. Explanatory Diagram: see facing page

II. The Regulation of pH

A. The nature of acids and bases according to the Bronsted-Lowry definition.

1. Limitations of the Arrhenius Concept

a. restricted definitions of acid and base

1) acid

2) base

b. applicability to aqueous solutions only

c. incorrect assumption that ionic bases (NaOH) are ionized to produce OH^- only when dissolved in H_2O.

d. incorrect assumption that excess H^+ in aqueous solutions of acids are formed by a simple equilibrium ionization of an acid as it is dissolved in water:

1) 1st objection:

2) 2nd objection:

27

2. How Covalent Acids and Bases actually ionize:

   a. Acids

      1) the existence of the hydronium ion:

      2) general equation representing the ionization of an acid in water:

      3) consequent classical definition of an acid:

   b. Bases

      1) the existence of the NH_4^+ ion:

      2) ionization of ammonia in water:

      3) general equation representing the ionization of a base in water:

      4) consequent definition of a base:

3. The Bronsted-Lowry Concept of Acids and Bases

a. extended definitions of acids and bases - these follow from the generalized equations of part 2.

1) acid:

2) base

b. Conjugate acid-base pairs

1) the ionization of an acid or a covalent base is an equilibrium reaction involving two acid-base pairs.

a) proton transfers occurring in both forward and reverse reactions:

Forward:

Reverse:

b) designation of the two acid-base pairs in the equilibrium reaction:

1st conjugate acid-base pair:

2nd conjugate acid-base pair:

2) generalization concerning conjugate acid-base pairs in any equilibrium reaction:

a) statement:

b) general equation for such a reaction:

c) further examples:

B. Relative Strength of Acids and Bases

1. Axioms based upon proton-donating tendency as a measure of strength

a. The 1st axiom:

1) as stated:

2) examples:

a) equilibrium mixture of HCl and H_2O

b) equilibrium mixture of HOAc and H_2O

b. The 2nd axiom:

1) as stated

2) examples:

a) case where starting acid and base are much stronger than products

b) case where starting acid and base are much weaker than products

2. Use of Table of Conjugate Acid-Base Pairs in determining the relative strength of acids and bases. Consult Appendix.

a. order of listing

b. order and extent of reactivity

31

c. examples:

1)

2)

3)

4)

5)

6)

C. Quantification of the Strength of Aqueous Solutions of Acids and Bases

1. Expressing the $[H_3O^+]$ in terms of pH

   a. the extent of ionization of water in itself

   b. K'_{H_2O} · the equilibrium constant

   c. K_{H_2O} · the ionization constant

   d. relative proportions of H_3O^+ and OH^- as a determinant of the degree of acidity or basicity of an aqueous solution

2. Measuring the acidity of dilute aqueous solutions in terms of pH

   a. two ways of expressing concentration (graded series)

   b. pH defined with examples

33 c. the pH scale for aqueous solutions, with ranges of common indicators included. Consult Appendix.

d. review of the use of logarithms as a tool for doing pH problems. Consult Appendix.

3. Partial ionization of weak acids and bases

   a. Acid-Base strength defined

      1) strong acids and bases

      2) weak acids and bases

      3) example of a weak acid

b. Equilibrium between reactants and products

1) equation representing HOAc's state in aqueous solution:

a) forward reaction

b) reverse reaction

c) equilibrium equation

2) equilibrium constant for HOAc

3) ionization constant for HOAc

a) concentration of unionized H_2O in aqueous solutions

b) rearrangement of equilibrium constant to get ionization constant

4) ionization constants for various acids and bases

a)

b)

c)

35

4. Use of Table of Conjugate Acid-Base Pairs for finding ionization constants. Consult Appendix.

5. Calculating the Ionization Constant. To be done after the problems on acids, bases and pH are completed.

   a. preliminaries to lab investigation. Consult Appendices on following topics:

      1) preparation of solutions of known concentration in terms of molarity or normality

      2) titration techniques

      3) use of the pH meter

   b. Review lab investigation, page

PROBLEMS

Name ______________________________

Science IV A Hour ____

Date ______________________________

WEAK ACIDS AND BASES, IONIZATION CONSTANTS, AND pH

I. Equilibrium Reactions Involving Conjugate Acid Base Pairs

Complete each of the following equilibrium reactions by:

1. indicating the symbols of the products formed by the forward reaction.
2. filling in the top blanks to indicate respective conjugate acid-base pairs (acid or base in the blank; pair number in the bracket)
3. filling in the bottom boxes to indicate the stronger acid and the weaker acid; the stronger base and the weaker base.
4. inserting equilibrium arrows to show whether the equilibrium favors the forward or reverse reaction.

	________(1)		________( )	________( )	________( )
a.	HNO_2	+	$CO_3^=$		
	☐		☐	☐	☐
	________(1)		________( )	________( )	________( )
b.	NH_3	+	$H_2PO_4^-$		
	☐		☐	☐	☐
	________(1)		________( )	________( )	________( )
c.	H_2O	+	$HPO_4^=$		
	☐		☐	☐	☐
	________(1)		________( )	________( )	________( )
d.	HSO_3^-	+	OH^-		
	☐		☐	☐	☐

37

II. For each of the following equilibrium reactions of weak acids with water in aqueous solutions, write out the equations expressing the equilibrium constant and the ionization constant:

a. $CH_3COOH + H_2O \rightleftharpoons$

$K' =$

$K =$

b. $HNO_2 + H_2O \rightleftharpoons$

$K' =$

$K =$

c. $H_2SO_3 + H_2O \rightleftharpoons$

$K' =$

$K =$

d. $H_3PO_4 + H_2O \rightleftharpoons$

$K' =$

$K =$

III. Look up the actual values of K for each of the acids of Part II. Then rearrange these acids in order from strongest to weakest.

K_{CH_3COOH} =

K_{HNO_2} =

$K_{H_2SO_3}$ =

$K_{H_3PO_4}$ =

IV. Problems on pH:

1. Find the pH of a solution if $[H_3O^+] = 4.24 \times 10^{-3}$.

2. Determine $[H_3O^+]$ of a solution if its pH is 10.6.

3. Find pH:

   a. $[H_3O^+] = 2.0 \times 10^{-5}$

   b. $[H_3O^+] = 3.4 \times 10^{-9}$

   c. $[OH^-] = 1.5 \times 10^{-7}$

   d. $[OH^-] = 1.96 \times 10^{-3}$

4. Find $[H_3O^+]$:

a. pH 1.25

b. pH 6.36

c. pH 13.60

5. Find $[OH^-]$

a. pH 10.26

b. pH 2.25

c. pH 13.60

Laboratory Investigation

DETERMINATION OF THE IONIZATION CONSTANT FOR BUTYRIC ACID

PURPOSE:

To carry out the procedure for obtaining the ionization constant of a weak acid.

THEORY:

Consider the equilibrium expression for a weak acid, such as butyric acid:

$$HC_4H_7O_2 \rightleftharpoons H^+ + C_4H_7O_2^-$$

$$\frac{[H^+]\ [C_4H_7O_2^-]}{[HC_4H_7O_2]} = Ka$$

Titrating this acid with a strong base such as NaOH and plotting these values on graph paper, a typical titration curve of a weak acid-strong base is obtained. Examination shows that when the butyric acid is half neutralized with NaOH, the butyric ion concentration will be equal to the undissociated acid and since these will then cancel out in our expression, the $[H^+] = Ka$:

$$\frac{[H^+]\ [C_4H_7O_2^-]}{[HC_4H_7O_2^-]} = Ka = [H^+]$$

We can thus find the $[H^+]$ from the pH.

MATERIALS: (per two students)

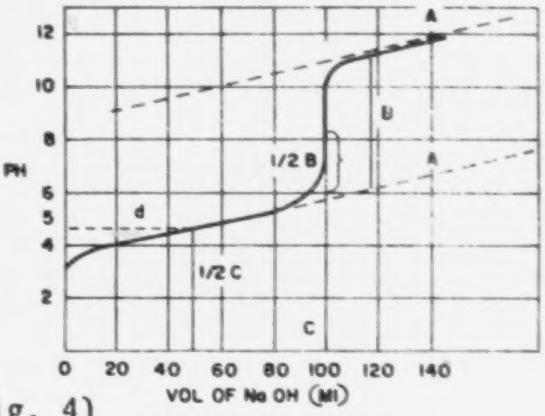
- 0.10M butyric acid
- 0.10M NaOH
- 250 ml beaker
- glass stirring rod
- burette tube
- stand and burette clamp
- pH meter and calomel electrode
- graph paper

PROCEDURE:

1. Prepare 0.10M solutions of butyric acid and sodium hydroxide.
2. Place 100 ml of 0.10M butyric acid in a beaker, immerse pH electrodes (glass and calomel) and electric stirrer.
3. Take initial pH reading.

42 4. Add NaOH in 10 ml increments, taking pH reading after each addition until 90 ml have been added. Decrease the size to one ml until 99 ml has been reached, then lower vol-reading to 0.1 ml until 101 ml have been added. Increase portions added to complete curve.

5. Plot pH vs. ml of NaOH. (See Fig. 4)



BUTYRIC ACID VS. NaOH

Figure 4.

6. Determine the end point by the half-height method, as follows (Fig. 4):

   a. Extend parallel portions of the curve by drawing two parallel lines.
   b. Drop a perpendicular to the base line of the graph, connecting the two parallel lines. Find the distance between the two parallel lines (B on Fig. 4)
   c. Locate one-half of this distance on the vertical section of the graph, extend this line (1/2 "B" on Fig. 4) to the base line of the graph and perpendicular to it.
   d. Note the volume of NaOH ("C" on Fig. 4).
   e. Take one-half of this volume, and at this point draw a vertical line up to your curve (1/2 "C" on Fig. 4). The concentration of the $(C_4H_7O_2)$ and $(H\ C_4H_7O_2)$ are equal.
   f. Find the pH corresponding to the half-way point on the curve "d" on Fig. 4. At this point the $(H^+ = Ka)$.
   g. Calculate the (H^+).

As soon as you have obtained your data, carefully clean all glassware and return materials to their proper order.

WORK DUE:

1. A graph plotting pH vs. ml of NaOH and showing end-point determination by half-height method.
2 Calculation of (H^+) and Ka.

6. Calculating the acidity of a weak acid using the Ionization Constant:

   a. sample problem: Find $[H_3O^+]$ of 0.1M HOAc

   b. solution:

      Step 1:

      Step 2:

      Step 3:

      Step 4:

      Step 5:

      Step 6-a.

      Step 6-b

c. percent of ionization of weak acids

d. verification of $[H_3O^+]$ of 0.1M HOAc

Laboratory Demonstration

PROBLEMS:

Name ______________________________

Science IV A Hour _____

Date ______________________________

FINDING THE DEGREE OF ACIDITY OF WEAK ACIDS

1. For a solution of 0.2M butyric acid:
    a. Find [H_3O^+]

    b. percent of ionization

    c. pH

2. Find the pH of 0.025N acid that is 3% ionized.

3. Find the pH of 0.1N acid that is 1% ionized.

4. Calculate the percent of ionization of 0.005N acid that has a pH of 4.

D. Buffers in General

1. Sensitivity of living organisms to slight changes in hydrogen ion concentration

   a. fluctuation of pH is very great with only small amounts of acid.

   b. the necessity of a homeostatic system for maintaining the constancy of $[H^+]$ of body fluids

   c. pH values of a variety of fluids associated with living organisms.

2. Principles of Buffer Action

   a. buffer system defined

   b. representing the conditions of a buffer system

   c. effects of adding OH^- and H^+

47

d. interaction of conjugate acid-base pairs in buffer reactions

3. Use of Buffers in the Laboratory

   a. for making standard solutions of constant pH to use for colorimetrically determining the pH of unknowns.

   b. for maintaining a given pH necessary for the optimal activity of a reaction.

   c. for keeping pH constant in cell and tissue culture media.

4. Determination of the pH of a Buffer System

a. the Henderson-Hasselbalch equation

1) its derivation

$$HOAc \; + \; H_2O \qquad\qquad H_3O^+ \; + \; OAc^-$$

step 1: $K = \frac{[H_3O^+][OAc^-]}{[HOAc]}$

step 2: rearranging the equation in terms of $[H_3O^+]$:

$$K[HOAc] = [H_3O^+]\,[OAc^-]$$

$$[H_3O^+] = K\,\frac{[HOAc]}{[OAc^-]}$$

Complete steps 3, 4, and 5 for an exercise in algebra:

step 3:

step 4:

step 5:

step 6:

$$pH = pK + \log \frac{[OAc^-]}{[HOAc]}$$

2) significance of each term appearing in the equation:

   a) since K is constant, therefore pK is constant.

   b) salt/acid ratio as a determinant of a buffer system's pH

   c) significance of a salt/acid ratio of 1.

3) protection of a buffer system against pH changes

   a) if a strong acid is added

   b) if a strong base is added

   c) effectiveness of a buffer is based upon its ability to maintain a fairly constant salt/acid ratio in spite of addition of H^+ or OH^-.

5. Sample problem demonstrating the action of a buffer:

Compare the effects of adding 10^{-3} mole HCl (0.03%g) to a dilute acid solution of 10^{-5}N and to a solution buffered with 0.175M $Na^{+}OAc^{-}$ and 0.100M HOAc. Both solutions have an initial pH of 5. Before making the comparison, verify this by calculating the pH of each solution before the 10^{-3} mole HCl is added.

1st: non-buffered system (10^{-5}N HCl)

initial pH =

final pH =

$\Delta pH_1 = pH_{initial} - pH_{final} =$

2nd: buffered system (0.175M $Na^{+}OAc^{-}$ + 0.100M HOAc)

initial pH =

final pH =

$\Delta pH_2 = pH_{initial} - pH_{final} =$

Which system showed the smallest ΔpH on addition of 10^{-3} mole HCl?

PROBLEMS:

Name ____________________

Science IV A Hour ____

Date ____________________

pH of Buffer Systems

1. Calculate the pH of a solution prepared by mixing 25 ml. of acetic acid with 10 ml of NaOH, both solutions being 0.1N.

2 . Calculate the pH of a solution prepared by mixing 100 ml of 0.1N sodium acetate with:

   a. 50 ml of 0.11N acetic acid

   b. 50 ml of 0.11N HCl

   c. 100 ml of 0.11N HCl

3. The pK of acetic acid is 4.75. Calculate the pH of a solution prepared by mixing 100 ml of 0.1N acetic acid with:

   a. 50 ml of 0.1N sodium acetate

   b. 100 ml of 0.02N NaOH

   c. 80 ml of 0.1N KOH

4. When 20 ml of 0.50N solution of a weak acid are mixed with 5.0 ml of 0.50N NaOH, the pH is found to be 5.65. What is the pK of the acid?

5. What volume of 0.10N NaOH must be added to 150 ml of 0.15N lactic acid to give a solution with pH = 3.60? (pK for lactic acid = 3.86)

Laboratory Investigation

THE FUNCTIONS OF A BUFFER SYSTEM IN MAINTAINING A CONSTANT pH

PURPOSE:

To provide experimental evidence in support of all that we said about buffer reactions.

MATERIALS:

weak acids and bases
salts of these weak acids and bases
strong acids and bases
burette tubes, stands and clamps
beakers, stirring rods, graduated cylinders, pipettes
pH meters, calomel electrodes and standard pH solutions
graph paper

PROCEDURE:

Since the work is to be somewhat open-ended, the type of buffer system you are to prepare and the procedure you follow in testing its capacity is up to you; however, it is suggested that you consider the following guidelines:

WORK DUE: a formal paper, type-written or in ink is to be submitted and must include the following:

1. preparation and use of materials.
   a. a description of your buffer system and how you prepared it, including exact concentrations of components.
   b. how you prepared your standard solutions of acid and/or base used for testing the buffer's capacity.
2. titration procedures and data.
3. graph plotting mE of H_3O^+ or OH^- against the pH of the buffer solution.
4. Calculations of theoretical pH and its comparison with actual pH as measured by a pH meter
   a. before adding H^+ or OH^-
   b. after adding H^+ or OH^-

6. Buffer systems in common use:
    a. Clark and Lubs

    b. Sorensen

    c. McElvaine (Consult Appendix)

D. The Buffer Systems of the Blood

1. Prime causes of the blood's tendency to shift towards acidity

2. The efficiency of buffers in maintaining constant pH of the blood.
    a. plasma proteins
    b. bicarbonates
    c. phosphates within the red blood cell
    d. hemoglobin and oxyhemoglobin

3. The blood-buffering agents and their operation
    a. organic buffers
        1) plasma proteins

a) Zwitterion form of an amino acid

b) amino acids as conjugate acids and bases

c) charged forms of dicarboxylic amino acids as dependent upon pH:

  c-1) pK_a defined

  c-2) determination of pK_a values:

  c-3) pI the isoelectric point

2) Hemoglobin and Oxyhemoglobin - refer to fig. 1

  a) comparative strength of hemoglobin and oxyhemoglobin

  b) reaction in lungs:

    b-1) dissoc. of reduced hemoglobin

    b-2) formation and release of CO_2

  c) reaction in tissues

    c-1) dissociation of oxyhemoglobin and consequent formation of reduced hemoglobin

    c-2) acceptance of H^+ by reduced hemoglobin

Figure 1. The Buffering Action of Hemoglobin

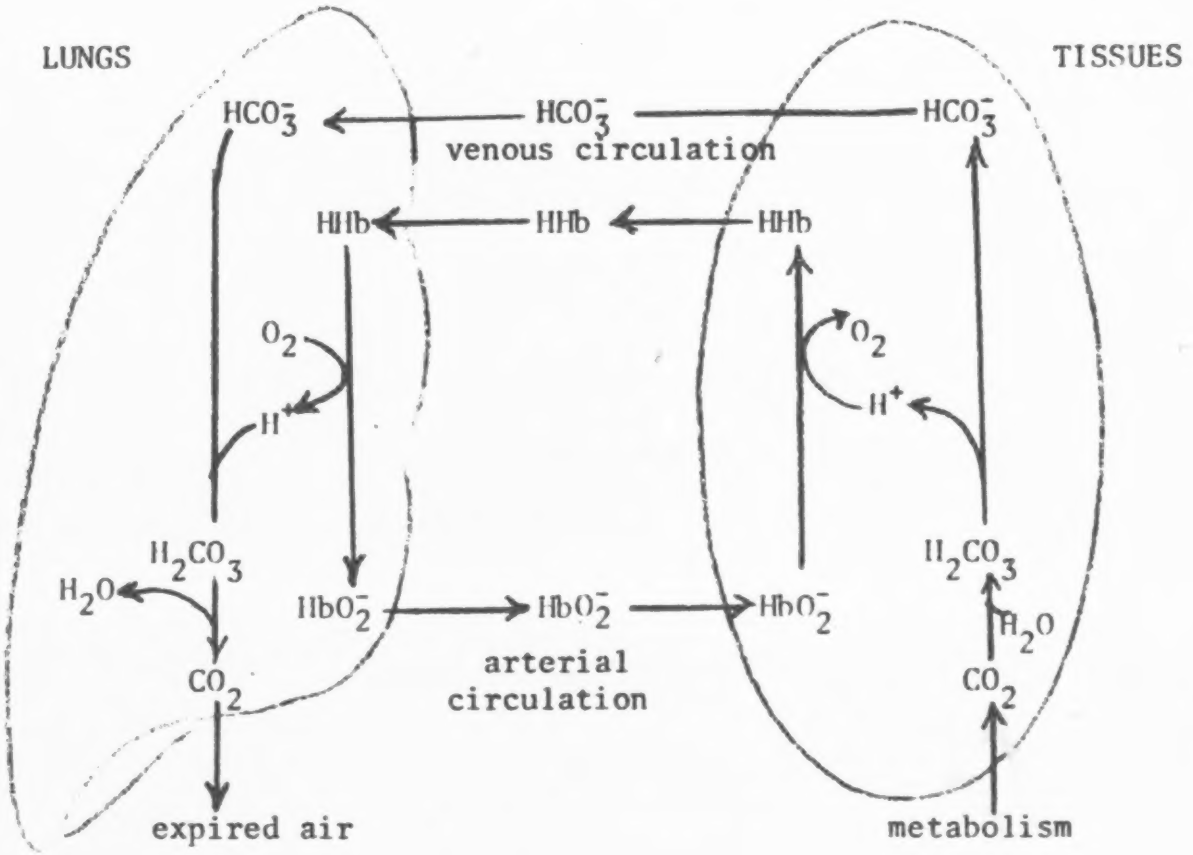
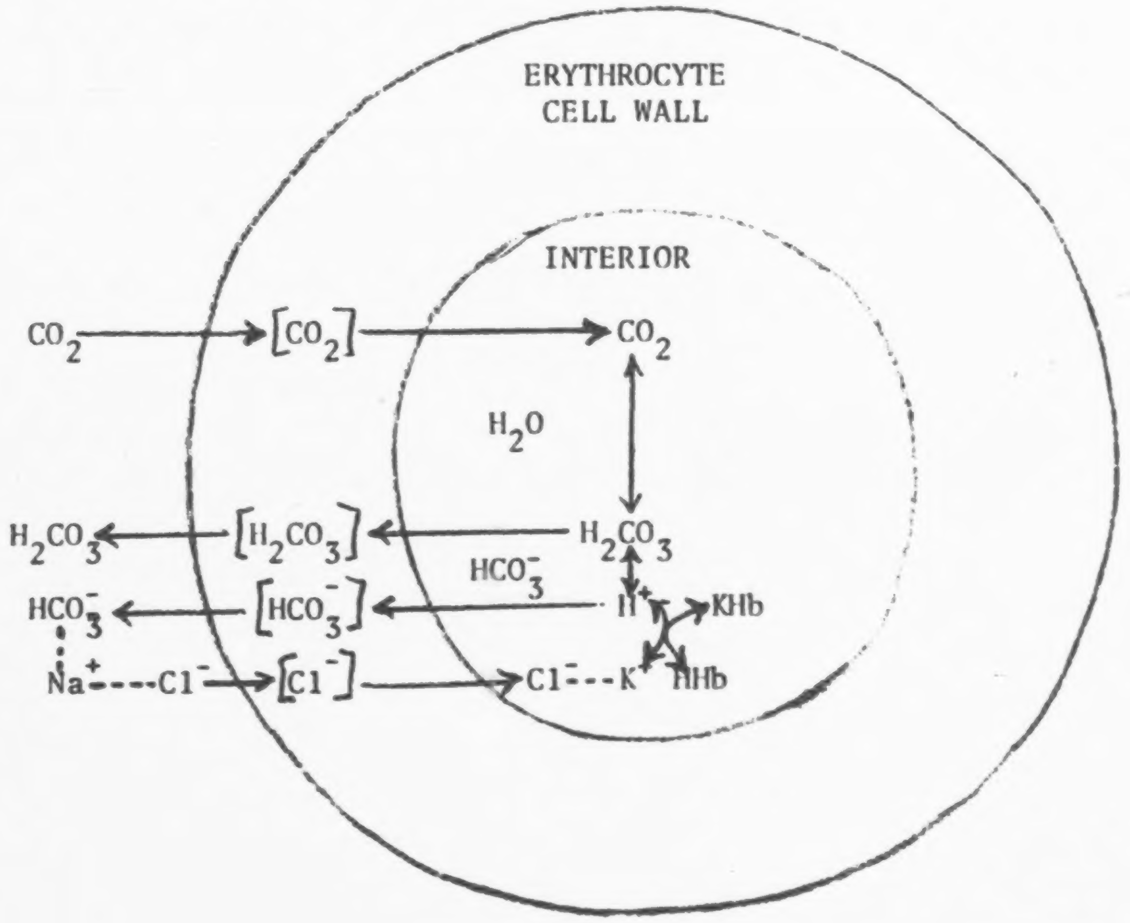

LUNGS
TISSUES
HCO_3^-
HCO_3^-
HCO_3^-
venous circulation
HHb
HHb
HHb
O_2
H^+
O_2
H^+
H_2CO_3
H_2O
HbO_2^-
HbO_2^-
HbO_2^-
H_2CO_3
H_2O
CO_2
arterial circulation
CO_2
expired air
metabolism

Figure 2. The Chloride Shift


ERYTHROCYTE CELL WALL
INTERIOR
CO_2
$[CO_2]$
CO_2
H_2O
H_2CO_3
$[H_2CO_3]$
H_2CO_3
HCO_3^-
HCO_3^-
$[HCO_3^-]$
H^+
KHb
Na^+
Cl^-
$[Cl^-]$
Cl^-
K^+
HHb

57

c-3) buffering action

c-4) isohydric transport of CO_2

d. Inorganic buffers

1) bicarbonates

2) inorganic phosphates

3) chloride shift (see fig. 2)

E. Causes and Effects of Homeostatic Failure in Maintaining the Acid-Base Balance of Body Fluids

1. Nature of disturbances in acid-base balance

   a. respiratory acidosis and alkalosis

   b. metabolic acidosis and alkalosis

2. Causes

   a. metabolic acidosis

   b. repiratory acidosis

   c. metabolic alkalosis

   d. respiratory alkalosis

59

3. Measurement of Acid-Base balance

   a. CO_2 content

   b. CO_2 capacity

   c. alkali reserve

4. The Role of the Kidney in Acid-Base Balance

   a. acid-base regulatory mechanisms

   b. influence of CO_2 tension on bicarbonate reabsorption

   c. action of a carbonic anhydrase inhibitor on excretion of bicarbonate

d. failure of acid-base regulation by the kidneys in disease

e. relation of K^+ excretion to acid-base equilibrium

III. Transportation of Nutrients and Waste Products

A. Transport of Food and Energy

1. Digestion

2. Enzymatic Hydrolyses

3. Mechanisms of Intestinal Absorption

4. Distribution of Absorbed Nutrients

B. Water Balance

1. Marine Environments

2. Fresh Water Environments

3. Terrestrial Environments

4. Extreme Environments

C. Excretion and Kidney Function

1. Nitrogen Excretion

2. The Urea Cycle

3. The Structure of the Kidney

4. Countercurrent Exchange Mechanism Important to Kidney Function

IV. Transportation and the Role of Hormones

A. The Endocrine System

1. Distribution and Types of Endocrine Glands

2. Nervous Control of Hormonal Secretions

3. Hormones as Chemical Regulators

B. Specific Functions of Hormones

1. Hormones Affecting Circulation

2. Hormones Affecting Glands

3. Hormones with a Metabolic Role

4. Hormones in the Reproduction Cycle

5. Hormones that Affect Endocrine Glands

V. Heat Exchange: Countercurrent Mechanisms for Heat Exchange

DYNAMICS OF BODY FLUIDS

INTRODUCTION:

Fluid dynamics, the study of the motion of fluids, can be a very extensive and difficult subject when pursued into all of its theoretical and practical aspects. This is especially true when attempts are made to describe real cases. Physical laws, however, can be very effective tools, despite the complexities encountered in nature.

One such case concerns the movement of extracellular body fluids through the circulatory system of the organism, facilitating the exchange of matter and energy between organism and environment. Such movement, being the circulatory system's prime function, hastens the exchange by insuring that the body fluids are continually cycled from places of depletion to places of saturation with respect to matter and energy. These body fluids, being subject to the homeostatic regulation of their pressure, flow, and composition, provide a portable environment for the organism's body cells, which are bathed in them.

In line with our theme of homeostasis of living organism, we shall first investigate the more fundamental qualitative and quantitative aspects of fluid dynamics and only to the extent that these aspects apply to the motion of the extracellular body fluids, the blood, lymph and serum.

In the fourth section, which concludes our study of the transport, regulation and exchange of matter throughout the living organism we shall be concerned with how certain diffusible materials are transported either passively (by diffusion) or actively (by energy-expenditure) across such structurally-interesting barriers as the capillary wall and the cell membrane.

Required Reading:		Dull, Metcalfe, Williams, Modern Physics "Fluids in Motion" Chapt. 8 pp. 211-215
	Part I:	Beyer and Williams, College Physics "Fluid Dynamics" Chapt. 11 pp 197-205
	Part II:	Geise, Cell Physiology "Colloidal Properties of Cells: Viscosity" Chapt. 4, pp 80-82. Beyer and Williams, College Physics "Fluid Dynamics" Chapt. 11 pp 206-207 Telfer and Kennedy, Biology of Organisms pp 251-252

Continued on next page.

Part III. Schmidt-Neilsen, *Animal Physiology*, Chapt. 2 pp 26-31.

Langley, *Homeostasis*, Chapter 5.

Beyer and Williams *College Physics*
"Fluid Dynamics" Chapt. 11, p. 207

Part IV. Solomon, "Pores in the Cell Membrane"
Scientific American Dec. 1960 (#76).

Holter, "How Things Get Into Cells"
Scientific American Sept. 1961 (#96).

Solomon, "Pumps in the Living Cell"
Scientific American Aug. 1962 (#131).

Robertson "The Membrane of the Living Cell"
Scientific American April 1962 (#151)

Hokin and Hokin "The Chemistry of Cell Membranes"
Scientific American Oct. 1965 (#1022)

Part I: BASIC DYNAMICS OF CIRCULATION IN PERIPHERAL BLOOD VESSELS

PURPOSE:

To study general aspects of peripheral circulation in a vertebrate animal and to determine some of the variables governing the flow-rate and flow-volume of blood in a closed system of vessels.

MATERIALS:

- microscope
- stage micrometer
- fish
- petri dish
- glass pipette
- cotton
- slide and/or cover-slip
- stop-watch
- graph paper

PROCEDURE:

1. Read the procedure and questions carefully before beginning!

2. Using a stage-micrometer, calibrate the distance between the teeth of the ocular micrometer in the eye-piece of your microscope. Why will this be necessary?

3. Place a live fish in a petri dish of water just deep enough to cover the animal when it is placed on its side. Water may be removed or added as needed with the glass pipette.

4. Gently place a water-soaked cotton-ball over the anterior two-thirds of the fish so that only the tail is exposed. This may take some time since your first attempts to subdue the fish are likely to fail!

   Once you succeed in placing the cotton over the fish, the weight should be enough to turn the animal on its side and hold it subdued in that position without harming it. If the fish is still able to escape, add more wet cotton.

5. After you are sure that the fish cannot escape from under the wet cotton, gently drop a plastic cover-slip over the exposed tail-fin to keep it flat and stationary. If the weight of the cover-slip is not sufficient, use a glass-slide instead.

6. Remove the stage-clips from your microscope and carefully place the petri dish on the stage, with the low-power objective lens in place.

7. Observe the thin outer portion (fin-part) of the fish's tail. Locate a vessel containing a stream of blood that is moving away from the heart. After you have found such a vessel, begin the work that follows.

Lab Investigation

Name ______________________

Science IVA Hour ______

Date ______________________

PART I: BASIC DYNAMICS OF CIRCULATION IN PERIPHERAL BLOOD VESSELS

PROBLEMS AND QUESTIONS

1. How can you be sure that the blood in the vessel you are looking at is moving away from the heart and not towards it? Describe how you determined this.

2. Is the flow of blood in the vessel steady or turbulent? Explain.

3. Determine the velocity $\left(\Delta x / \Delta t\right)$ of a given red blood cell as it travels through the vessel you are studying.

This can be done by lining up a length of the vessel with the span of teeth of the ocular micrometer. With your eye, you should be able to follow the motion of a single red blood cell through a measured length $(x_2 - x_1)$ of the vessel. With a stop-watch, measure the time it takes for a red blood cell to travel from x_1 to x_2 (points marked by the two most extreme teeth at either end of the ocular micrometer).

Start the watch at the instant the red blood cell reaches x_1 and stop it the instant the cell reaches x_2.

The velocity is given by:

$$\Delta x / \Delta t = \frac{x_2 - x_1}{t_1 - t_0}$$

Report the measured velocity for the red blood cell in microns per second on the chart of number 5 on next page. What is this velocity in terms of meters per second?

4. Measure the diameter of the lumen of the vessel you have been studying and from this measurement, obtain the radius in microns. Report this value in the chart in #5 below.

5. Repeat numbers 3 and 4 for at least three other vessels of differing radii and complete the following chart:

VESSEL	RADIUS (μ) of lumen	BLOOD CELL VELOCITY (μ/sec)

6. On graph paper, plot velocity against radius for the data you have obtained in number 5.

   a. Does the curve indicate that velocity is a function of the radius?

      that is; is it true that: $v = f(r)$??

   b. If so, find an equation expressing the relationship that exists between the independent variable, r, and the dependent variable, v.

7. From the data you have gathered, compute the flow-rate of blood in each vessel of differing radius.

   Flow-rate is defined as the volume of blood flowing past a given point in a vessel, per unit-time.

   that is:

   $$\text{Flow-rate} = V/t$$

   where V/t can be expressed in milliliters (ml) per second, or in microliters (μl) per second.

   1 milliliter (ml) = 1 cm^3 (or "cc") = 10^{12} cubic microns

   1 microliter (μl) = 10^{-3} ml = 10^{-6} liter

In order to calculate volume, assume a vessel to be a perfect cylinder of volume $\pi r^2 l$, where r is the radius of the lumen.

Then complete the following chart:

VESSEL	RADIUS (μ)	VELOCITY (μ/sec)	V/t $\left(\mu l^{3}/\text{sec}\right)$
data in these 1st 3 columns is the same as that in the chart of #5			

8. From the data you obtained in #7, plot flow-rate against radius.

   a) Is flow-rate a function of the radius?

      that is; is it true that:

      $V/t = f(r)$?

   b) If so, write a statement of proportionality - or even better, an equation expressing the relationship that exists between the independent variable r and the dependent variable V/t.

9. Next, plot flow-rate against velocity.

   a) Is the flow-rate a function of velocity?

      that is; is it true that:

      $V/t = f(v)$?

   b) If so, write a statement of proportionality, or better, an equation expressing the relationship that exists between the independent variable v and the dependent variable, V/t.

Part II: BASIC DYNAMICS OF CIRCULATION IN PERIPHERAL BLOOD VESSELS

PURPOSE:

To get the investigator to think about what effect the total cross-sectional area through which blood is allowed to pass in a tissue has on the blood pressure and flow-volume.

MATERIALS:

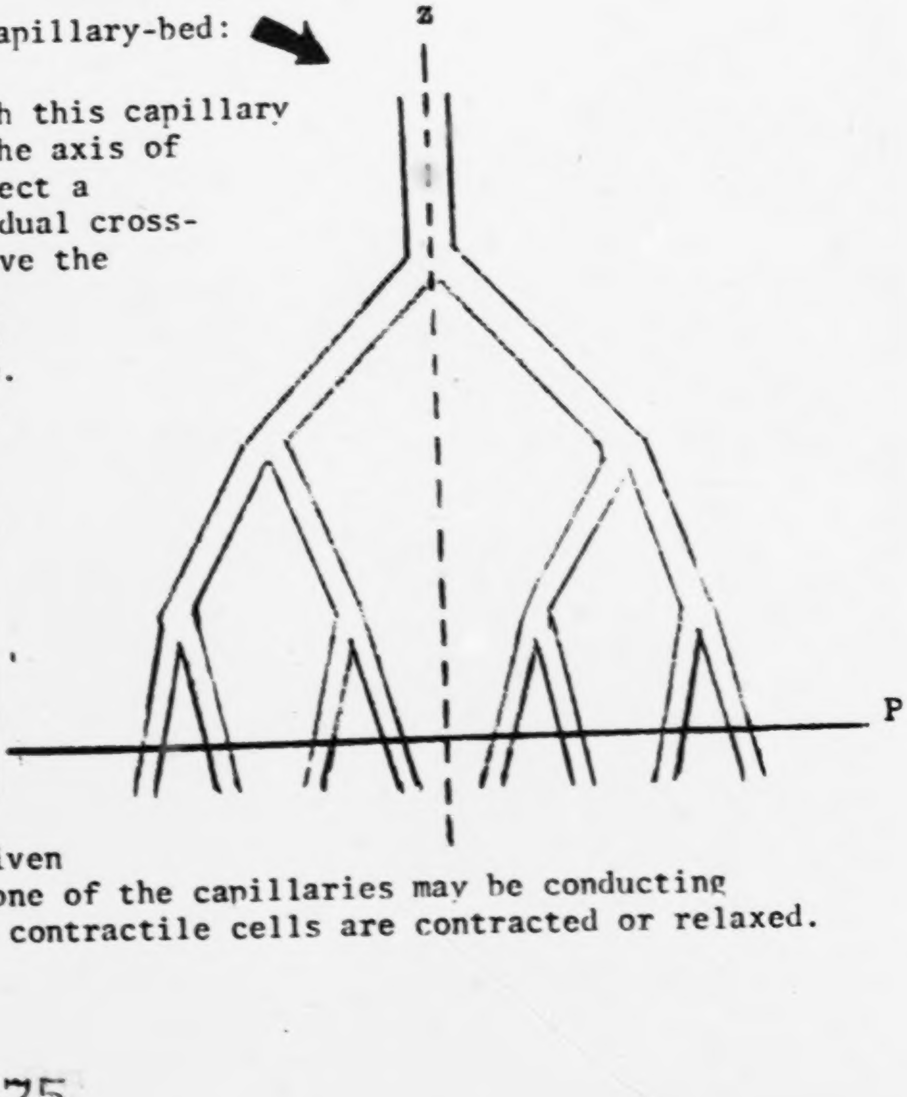
graduated cylinders, Y-tubes, hoses of varying diameters and running water - in addition to the materials used in the last investigation.

BACKGROUND AND PROCEDURE — SECTION A:

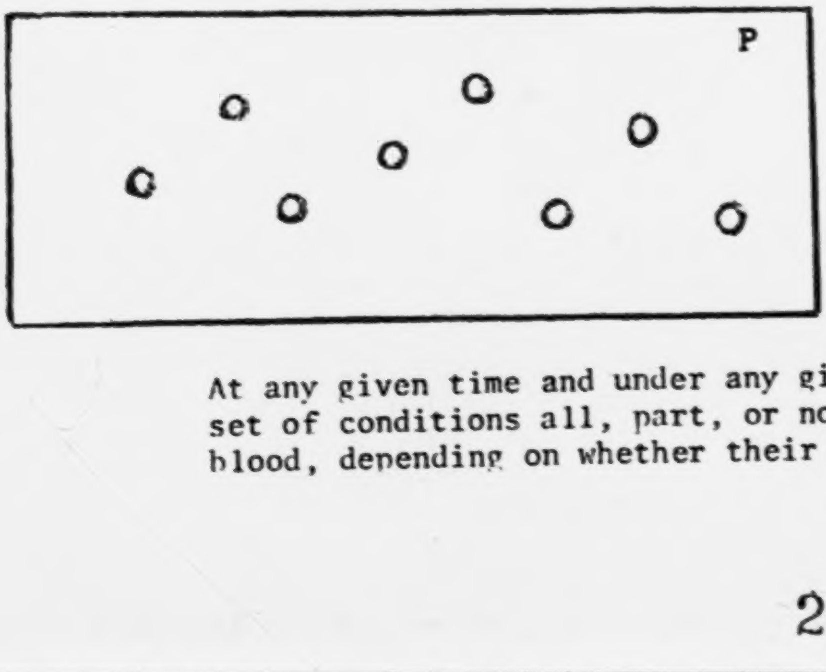
Capillaries are unique among blood-vessels in that they possess contractile cells at various locations on their outer surfaces. These cells work independently of the central nervous system, receiving their stimuli from chemicals transmitted in the body fluids.

The presence of these valve-like cells permits capillaries to be constricted to a degree that will stop the flow of blood through them - or to relax and dilate to their large possible cross-sectional area, permitting an unrestricted flow of blood. Consequently, the capillary-beds that exist in every tissue of the body provides us with a situation where A, the total cross-sectional area can vary from zero to some maximum value, at least theoretically.

Consider the following idealized capillary-bed:



As shown, plane P is passed through this capillary bed so as to be perpendicular to the axis of symmetry z. The plane will intersect a number of capillaries whose individual cross-sectional areas can be added to give the total cross-sectional area that is available for the passage of blood at the location given by the plane. This intersection is shown below.



At any given time and under any given set of conditions all, part, or none of the capillaries may be conducting blood, depending on whether their contractile cells are contracted or relaxed.

72

Using running water, graduated cylinders, Y-tubes, and hoses of varying diameters, design a simple model of the capillary bed just described and use it to help you answer the following questions.

Lab Investigation

Name ______________________________

Science IV Hour _____

Date ______________________________

Part II: BASIC DYNAMICS OF CIRCULATION IN PERIPHERAL BLOOD VESSELS

QUESTIONS - SECTION A:

1. Write a statement of proportionality that expresses the relationship that you believe exists between pressure and total cross-sectional area.

   Can you perform a simple demonstration that will support your hypothesis? Describe in full.

2. Do likewise for the relationship you believe exists between flow-volume (per unit-time) and total cross-sectional area.

   Can you perform a demonstration in support of your hypothesis? Describe in full.

3. Finally, do the same for pressure and volume (per unit-time).

Describe a demonstration in support of your hypothesis.

Is the relationship between pressure and volume the same as it is for the ideal gas law?

BACKGROUND AND PROCEDURE - SECTION B:

Because of their size, it will be impossible for us to measure capillary-pressures directly. We will, however, investigate a way of estimating the total cross-sectional area through which blood is flowing.

Prepare a live fish for observation as you did in lab investigation, Part I. Locate as many different (no repeats) capillaries as you can. A capillary is recognizable by the following characteristics:

a. a capillary's inner diameter is sufficiently small enough to permit the passage of only a single red blood cell at a time.

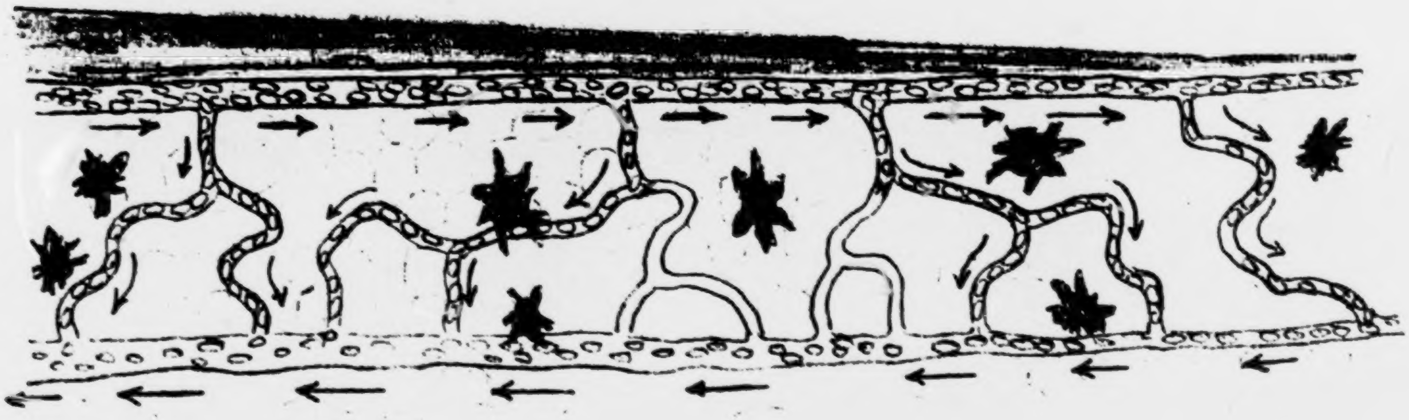
b. capillaries often lead from larger vessels at right angles or nearly right angles.

c. capillaries meander rather than pass straight through the tissues they nourish.

d. capillaries usually do not run parallel and adjacent to fin-rays and bones, but rather carry blood through the thin tissues between these structures.

e. at any given time, capillaries may or may not be carrying moving blood, depending upon whether the contractile cells they possess are dilated or constricted.

The drawing below illustrates each of these characteristics:



(large black star-shaped cells are chromatophores)

Now answer the following questions.

Lab Investigation

Name ______________________________

Science IV Hour ____

Date ________________________

Part II: BASIC DYNAMICS OF CIRCULATION IN PERIPHERAL VESSELS

QUESTIONS - SECTION B:

1. Tally and record the sums of capillaries falling into either of two categories n_o and n_c, as shown in the sample-space below:

n_o, the number of capillaries with moving blood	
n_c, the number of capillaries with motionless, nearly-motionless, or no blood at all	
$n = n_o + n_c$, the total number of different capillaries surveyed	

2. Compute the average maximum cross-sectional area $\bar{a}$, for at least five capillaries randomly sampled among only those that have moving blood.

r	a
TOTAL:	

$\bar{a}$ = ____________

3. A, the total cross-sectional area across which blood is flowing in a capillary-bed is given by:

$$A = pN\bar{a} = \left(\frac{n_o}{n_c+n_o}\right)N\bar{a}$$

where N = the total number of capillaries in the capillary-bed of the particular tissue in question

$\bar{a}$ = the mean cross-sectional area for a capillary

$p = \dfrac{n_o}{n_c + n_o}$, a ratio, the value of which is determined by random-sampling. It represents the probable fraction of capillaries that are dilated out of the total number of capillaries.

n_o = the number of surveyed capillaries that are dilated.

n_c = the number of surveyed capillaries that are closed.

n = the total capillaries surveyed.

a) Given the restriction that $0 \leq p \leq 1$, complete the following:

Value of p:	corresponding values for:	
	n_c	n_o
p - 1		
$0 < p < 1$		
p - 0		

b) The sum, $n_c + n_o$ can never be greater or less than __________ in the equation.

4. For the set of capillaries you surveyed, compute the value for p. What is the significance of this value in view of the range of values for n_c and n_o that you obtained in question 3a?

   Hint: In terms of percent, approximate that portion of the total possible cross-sectional area A, that was available for the passage of flowing blood at the time you made your observations.

5. How would you go about determining N in the equation given in question 3? Describe in full.

6. Why is it difficult, if not impossible for you to determine even a close approximation of A for the tissue you have been examining?

7. Assuming your hypothesized statements of proportionality (see questions for Part II, section a) are correct, explain each of the following phenomena in terms of the variables we have been concerned with in this lab work.

   a. blushing

   b. redness of face and limbs after strenuous activity

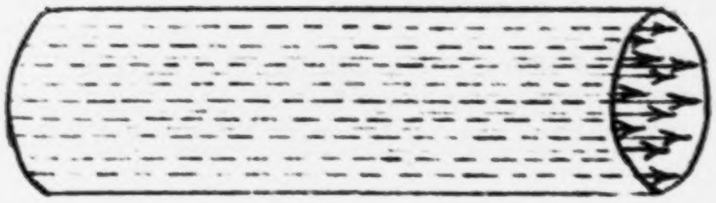
   c. redness of face in people that are over-weight.

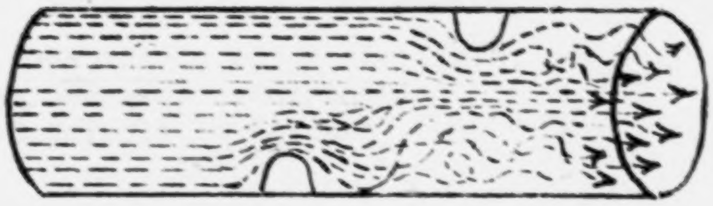
   d. flushing of face and subsequent black-out on standing at attention for a long period of time.

   e. the large drop in blood pressure that usually commpanies shock.

79

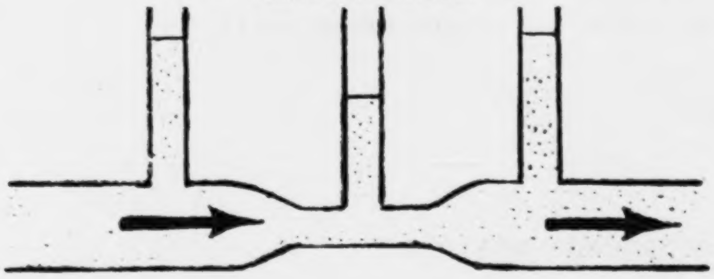
STREAMLINE vs. TURBULENT FLOW



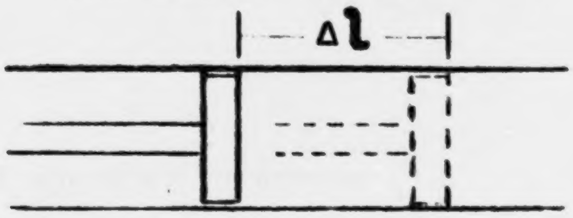


STEADY -	TURBULENT -
IRROTATIONAL -	ROTATIONAL -
INCOMPRESSIBLE -	COMPRESSIBLE -
VISCOSITY CONSTANT	VISCOSITY VARYING

VENTURI TUBE

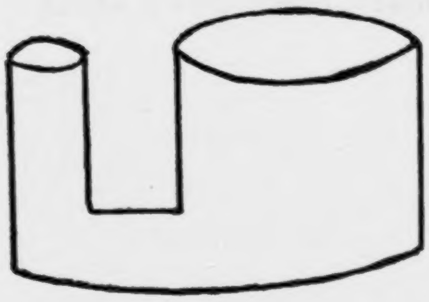


WORK DONE BY A FLUID IN MOTION

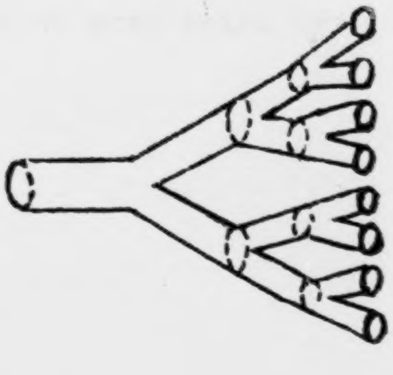


APPLICATIONS:

A. Hydraulic lift



B. Biramous Capillary System



I. Simple Fluids in Motion

A. Types of Flow

1. streamline flow (ideal)

2. turbulant flow (non-ideal)

3. assumptions in working with models of fluids in motion

B. Factors Affecting Velocity and Pressure of a Simple Fluid Moving in a Horizontal Tube

1. the Venturi Tube

a. inverse relationship between velocity and diameter

b. inverse relationship between velocity and pressure

c. calculation of a fluid's velocity from the difference in pressure in two vertical tubes.

81

2. Bernouilli's Principle

   a. an explanation for the variation in pressure exerted by a moving fluid when its velocity is changed.

   b. Bernouilli's Equation

   c. applications

C. Work Done by Fluids in Motion

   1. work-energy equation

   2. work done when a volume of fluid enclosed in a tube is displaced by the application of a pressure.

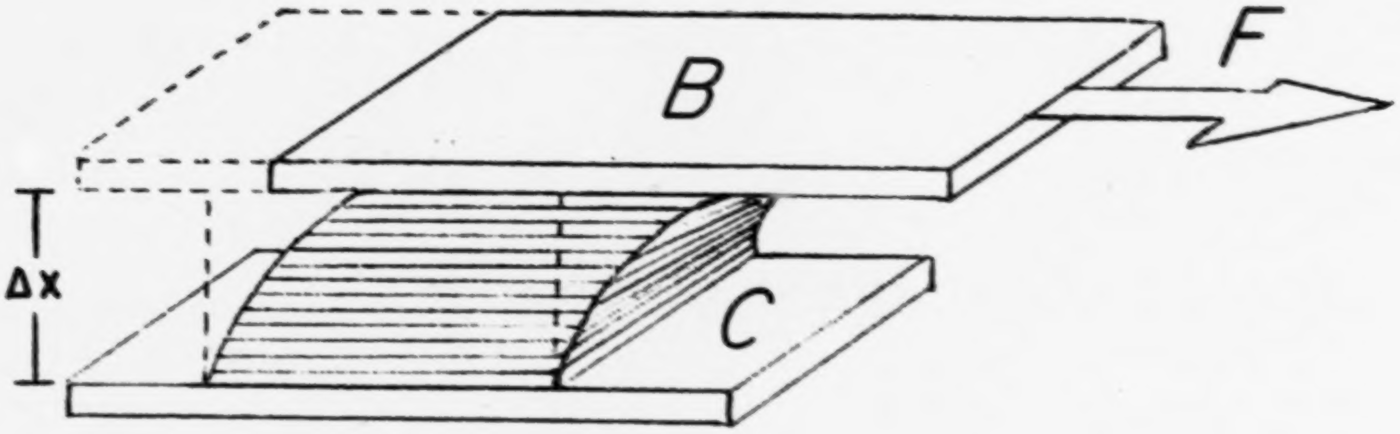
      a. work = force x distance

      b. derivation of an equation for work = pressure x volume

c. applications

1) hydraulic lift

2) biramous capillary system



in the figure above:

1) B and C are planes separated by a layer of fluid Δx in thickness

2) the relative speed of the two planes is given by Δv.

3) the faces of B and C in contact with the fluid are both equal to A

4) F is the viscous force which hinders the relative motion of B and C in sliding past each other.

II. Viscous Fluids in Motion

A. Viscosity defined

B. Derivation of an Equation for the Viscous Force Exerted by a Fluid

1. The size of a viscous force,F is defined in terms of the apparatus used to measure it. In the diagram on the facing page, it is defined as the force which hinders the relative motion of the two parallel surfaces B and C.

2. Equation for a viscous force, F:

3. Proportionality constant, η

85 4. Merit of Computing stress per unit velocity per unit spacing.

C. CGS units for viscosity

1. Dimensional analysis of the equation for η:

2. The Poise

#. The Centipoise

D. Standards for Viscosity

1. water

2. other common fluids:

TABLE OF VISCOSITIES IN CENTIPOISES AT 25°C

Diethyl ether	0.22
Water	0.89
Ethylene glycol	14
Olive Oil	67
Glycerol	950

E. Factors Affecting the Viscosities of Fluids

1. Colligative factors
    a. temperature

    b. pressure

    c. molar concentration

2. Non-colligative factors
    a. particle size and shape

    b. solvation of lyophilic particles

    c. elongation and intertwining of particles

    d. formation of brush-heap structures

F. Methods of Measuring the Viscosities of Fluids

1. in vivo method

2. falling ball method

3. Coulette Viscometor

4. Ostwald Viscometor: See Appendix for theory and use

   a. relative viscosity

   b. kinematic viscosity

III. The Motion of Body Fluids in the Vertebrate Circulatory System

A. Gross structural features responsible for the unidirectional flow of circulatory fluids

1. Basic theoretical requirements for a unidirectional circulatory system

2. Types of circulatory systems (See Diagrams on facing page)

a. open

b. closed

c. main advantages of closed

1)

2)

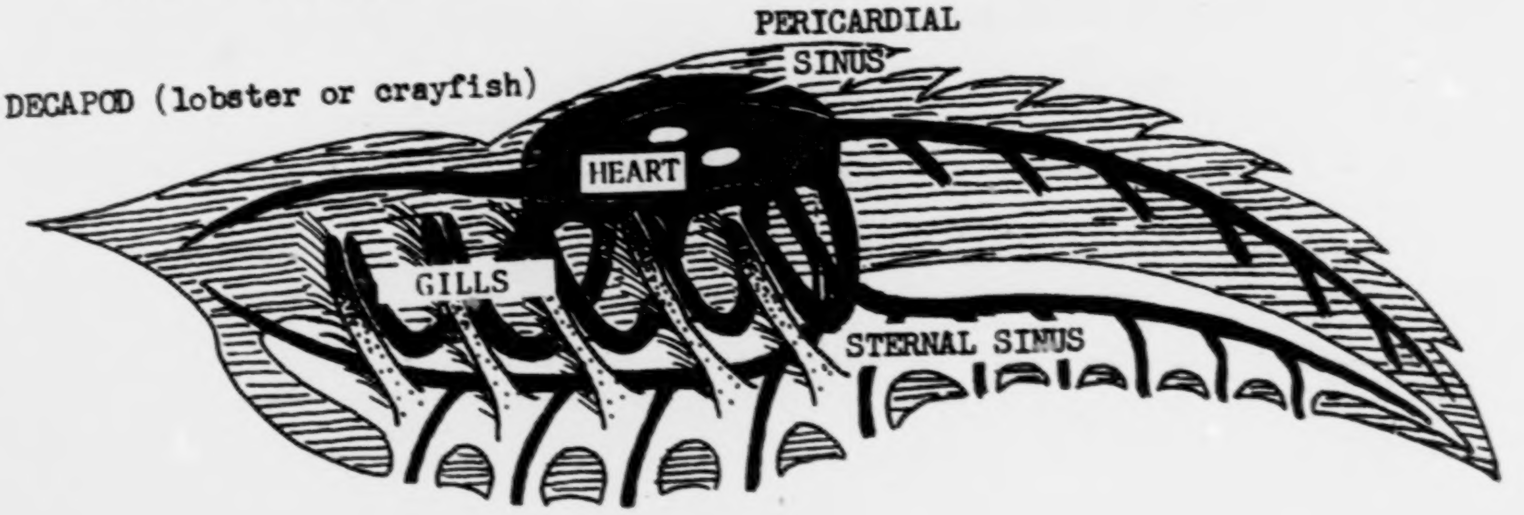
3)

COMPARISON OF CIRCULATORY SYSTEMS OF REPRESENTATIVE ORGANISMS

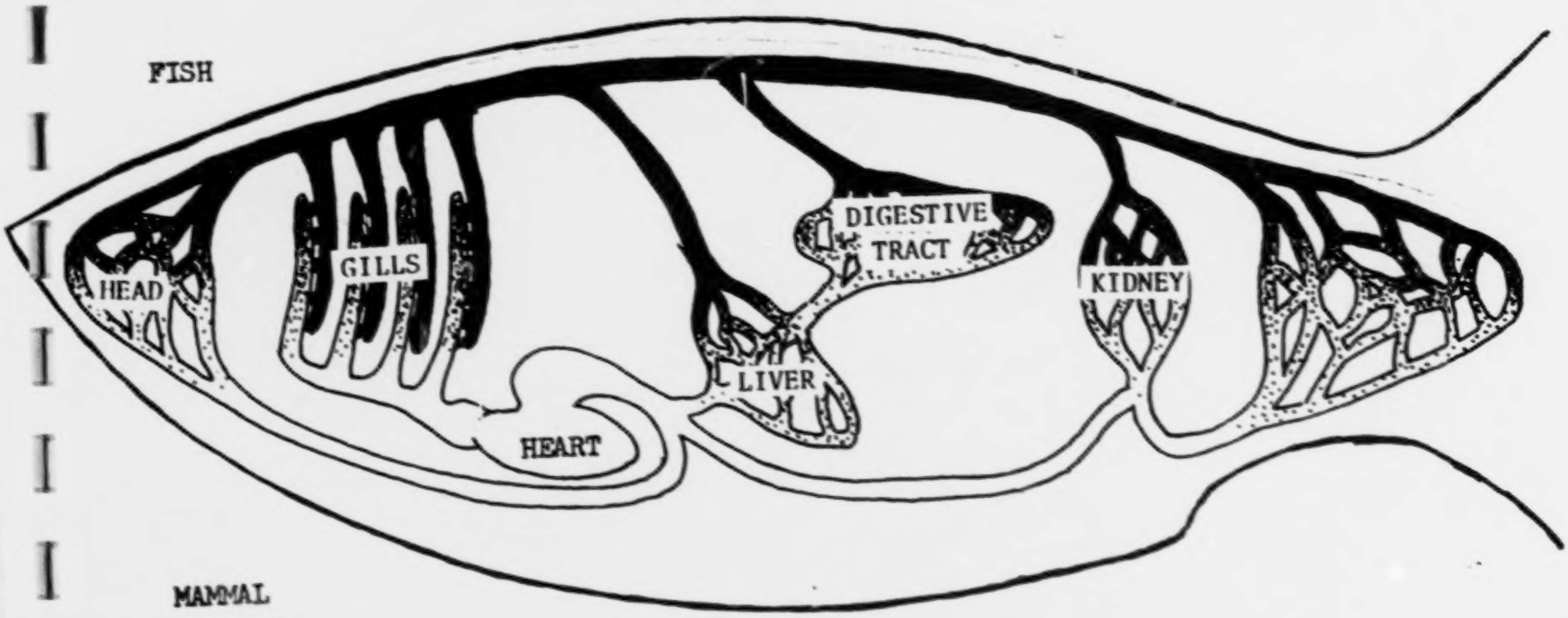
black = blood rich in oxygen
white = blood poor in oxygen

arteries carry blood away from heart
veins carry blood towards the heart

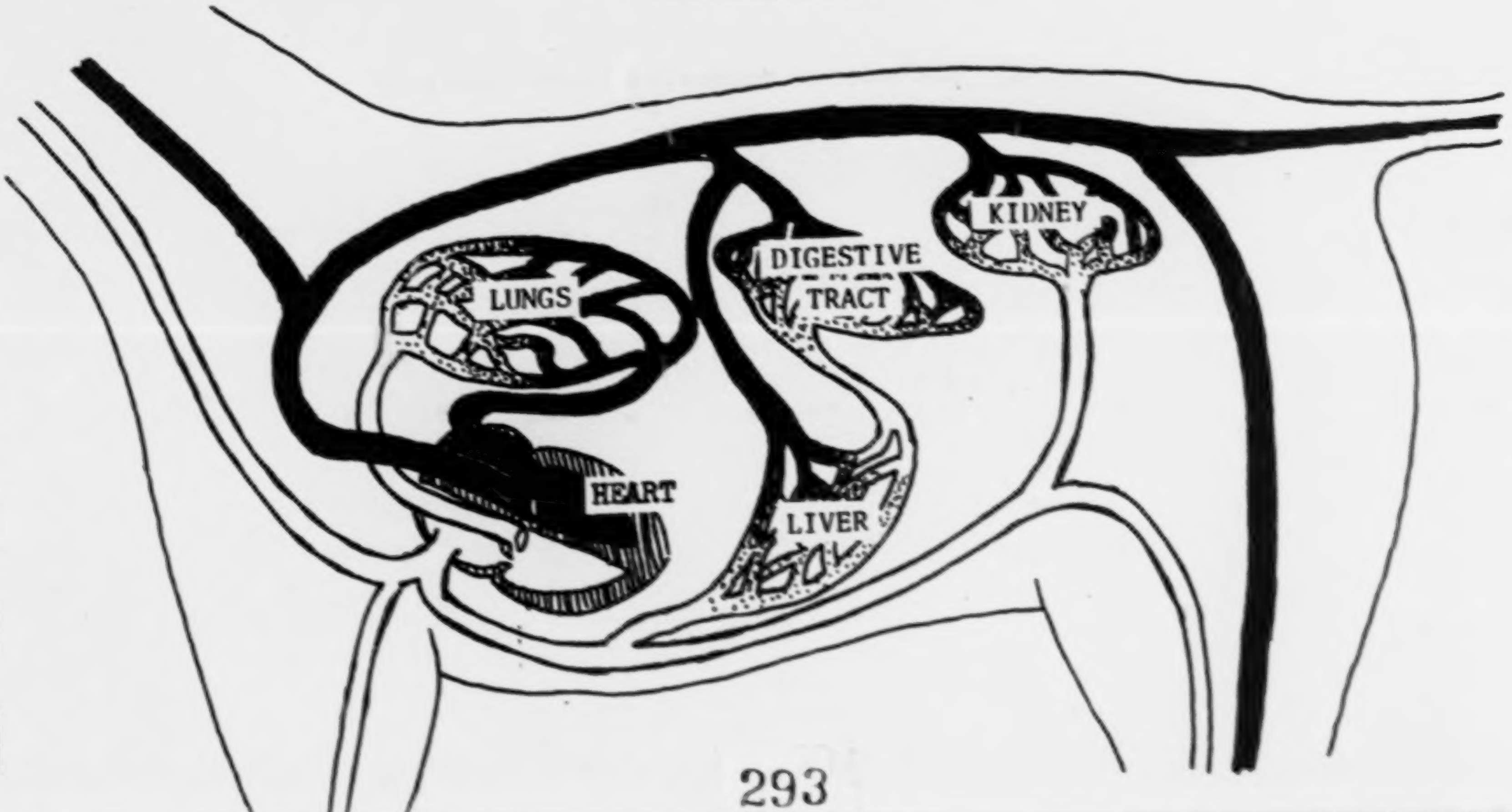
DECAPOD (lobster or crayfish)


PERICARDIAL
SINUS
HEART
GILLS
STERNAL SINUS

FISH


DIGESTIVE
TRACT
GILLS
HEAD
KIDNEY
LIVER
HEART

MAMMAL


KIDNEY
DIGESTIVE
TRACT
LUNGS
HEART
LIVER

3. Details of a closed system

    a. the heart as a driving force

        1.) anatomical features

        2.) pulses in the heart's contraction cycle

            a) diastole

            b) systole

            c) methods of measuring blood pressure

3) carrying capacity

4) regulation of beat by nerves and hormones

The material on page 91 may be found

TITLE **Life Science, Intermediate Level**

AUTHOR **Milton S. Lesser**

PUBLISHER **AMSCO School Publications, Inc.**

PAGE NO. **112**

b. the vessels

1) arteries

2) arterioles

3) capillaries and capillary beds

4) venules

5) veins

The material on page 93 may be found

TITLE Life Science, Intermediate Level

AUTHOR Milton S. Lesser

PUBLISHER AMSCO School Publications, Inc.

PAGE NO. 104

c. Resistences encountered as body fluids are moving moving through the circulatory system

1) resistence offered by valves

2) frictional resistences of surfaces

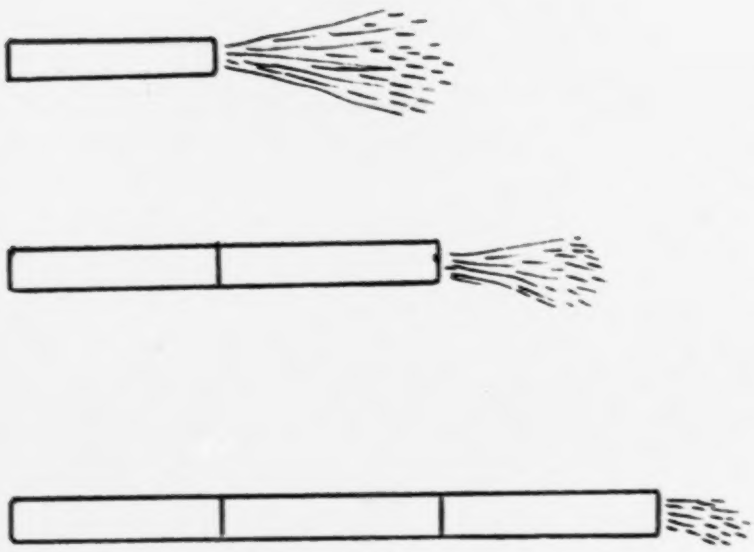
3) length, diameter and cross-sectional area of vessels

4) physical nature of the fluid being circulated

    a) volume

    b) density

    c) viscosity



B. Fluid Dynamics as Applied to the Movement of Viscous Fluids Through a Circulatory System

1. Pressure and flow defined

   a. pressure

   b. flow volume

   c. flow rate

2. Faucet and Hose model (see figures on facing page)

   a. three situations for single length $L = S_1 - S_0$

      1st: faucet and nozzle wide open

      result:

      2nd: faucet wide open; nozzle closed down tight

      result:

      3rd: faucet wide open; nozzle opened little by little

      result:

      The following conclusion can be made concerning the relationship that exists between output flow and hose pressure:

      The following inference can be made concerning the effects that increasing hose length has on output pressure:

97

b. effects of increasing hose length:

1) 2L:

2) 3L:

Conclusion regarding the pressure at a fixed point as hose length is increased:

Faucet-and-Hose Model

2. Poiseuille (Laminar) Flow ( )

a. the nature of Poiseuille flow

1) Poiseuille flow defined

2) properties of Poiseuille Flow

a)

b)

c)

d)

e)

3) Conditions required for Poiseuille flow to occur:

a) the Reynolds number, R_e - an empirical relation used to decide in advance whether or not a particular case of flow will be laminar.

b) interpretation of the Reynolds number for a given case:

1) if $R_e < 1000$:

2) if $R_e > 2000$:

3) if $1000 < R_e < 2000$:

99 b. Poiseuille Deduced the Following Relationship in Regard to the Viscous Flow of Blood in Vessels:

c. Apparent contradictions between Poiseuille's statement and the conclusion drawn from the behavior of the faucet-and-hose model:

1st apparent contradiction:

According to Poiseuille; $P \propto L$
but in the faucet-and-hose model, it was said that the longer the hose the lower the outlet pressure.

The apparent inconsistency is resolvable by taking into account:

Thus, the pressure P_1 at fixed point S_1 ________________ proportionately with each additional length of hose.

Thus, for length 2L:

and for length 3L:

This is true because with each additional length increment, the resistence to flow ______________ and the pressure gradient between the faucet end and the outlet end becomes ____________.

But it is also true that:

P_1 outlet P_2 outlet P_3 outlet

Since Poiseuille was speaking of pressure at a fixed point and *not* the outlet pressure, his statement that pressure is directly proportional to the length is correct.

2nd apparent contradiction:

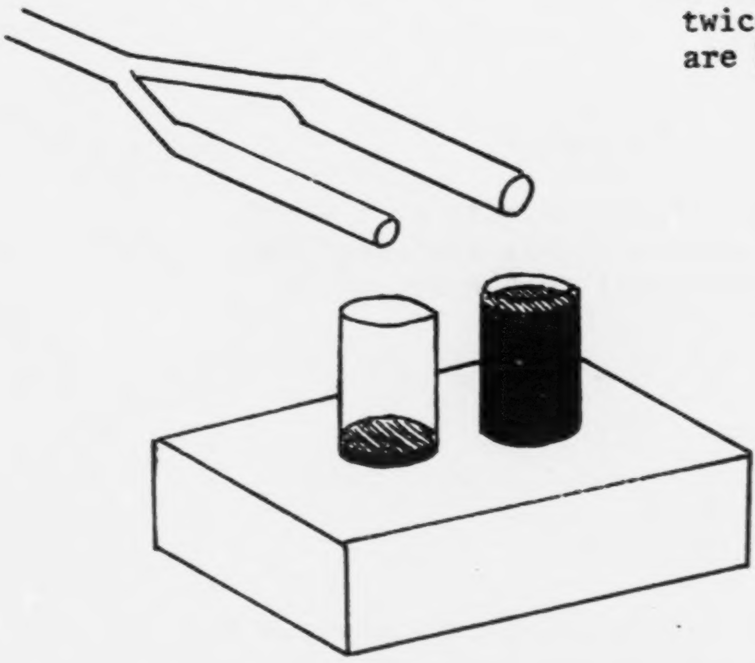
Poiseuille states that $P \propto \frac{1}{R^4}$

It is understandable that the pressure increases as the radius decreases, but why to the 4th power of the radius?

Since flow is easier to measure than pressure, Poiseuille's statement of proportionality can be rearranged as follows:

thus:

101



In the diagram to the left tubes 1 and 2 are of the same length, but tube 2 has a radius twice that of tube 1. Assume also that the tubes are horizontal to the earth's surface.

Since the volume of a cylinder is $\pi r^2 L$ it would seem that after allowing water to flow through for a short time - V_2, the volume of fluid collected from tube 2 would be 4 times that of V_1, the volume of fluid collected from the first tube:

$V = \pi r^2 \ L$ where π and L are constant

Let $r = 1$ cm and $L = 1$ cm

Then $V_1 = \pi (1 \text{ cm})^2 \ (1 \text{ cm}) = \pi \text{ cm}^3$

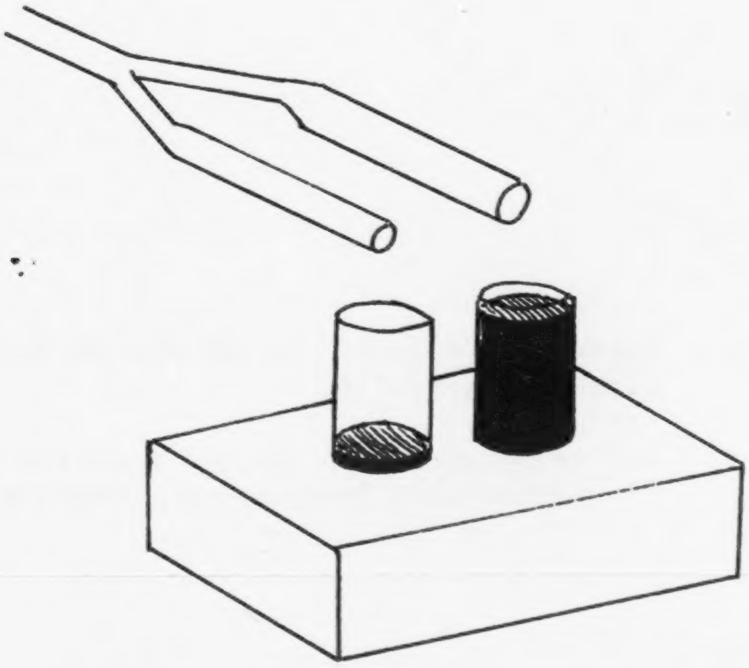
and $V_2 = \pi (2\text{cm})^2 \ (1 \text{ cm}) = 4 \pi \text{cm}^3$

But if the actual experiment is conducted it will be found surprisingly that $V_2 = 16 V_1$. Thus for every ml. coming out of the smaller tube, 16 ml will flow out of the larger. This follows because the radius is larger by a factor of 2 and $2^4 = 16$. Thus, $V_2 = 16 \quad \text{cm}^3$

Thus, the volume of fluid flowing through a vessel is described by the following statement of proportionality:

Name ______________________________

Science IVA Hour ______



Poiseuille tells us that:

d. Poiseuille's equation expressing total flow (derived by the use of calculus and some rather elaborate ideas from advanced fluid-dynamics).

c. Poiseuille's equation and its applicability to the circulatory system:

1) terms appearing in the equation that may be essentially regarded as constant:

2) terms appearing in the equation that are variable:

C. Regulation of Pressure and Flow of Circulatory Fluids by Nerves and Hormones

1. Regulation of Heart Beat

   b. Regulation from sources outside the heart

      1) Loewi's Experiment

      2) Nerves and **neurohormones**

      3) Acetylcholine and Adrenolin

      4) Feedback mechanism

   c. Regulation from within the heart itself: pacemakers

2. Regulation of blood pressure by action on larger vessels

   a. factors governing vasoconstriction and vasodilation

   b. feedback mechanisms that compensate for decreased blood pressures

3. Regulation of capillaries

   a. the many roles of histamine

   b. effects of capillary dilation on permeability

   c. white reaction & triple response

4. Effects of drugs on peripheral circulation

Laboratory Investigation

CAPILLARY CIRCULATION IN MAN:

EFFECTS OF MECHANICAL STIMULATION OF THE BLOOD VESSELS OF THE HUMAN SKIN

There are several methods available for studying the phsiology of the cutaneous circulation in man. The study of skin color and its changes is perhaps the most valuable. We shall be most concerned with this method in the following exercises. Select as a subject a person with "flushed" skin.

The White Reaction: If a blunt point is drawn with light pressure across the skin of the forearm, chest, or back, there is formed a white line due to the expelling of blood from the minute vessels of the skin. This white line disappears within a few seconds and is followed, in most subjects, by a second white line which may persist for a period of from four to five minutes. This reaction is due to an active contraction of the minute vessels of the skin (terminal arterioles, capillaries and first collecting vessels) which is apparently in response to slight stimulation of the skin by stretching.

One of the best methods for eliciting the above reaction is by lightly drawing across the skin the flat end of a ruler, whose edges have been rounded. The amount of pressure exerted should only be a little more than is necessary to expel the blood from the superficial vessels.

Select a subject for this experiment and proceed as directed above. Is the white line confined to the area over which the stimulating object was drawn or it it diffuse? On the basis of this observation, what are your conclusions regarding the types of skin vessels involved in the reaction?

If the stimulus is too severe, a red line will develop. In that case, the experiment should be repeated until the proper strength of stimulus has been determined. Time the onset and disappearance of the reaction in different individuals and on different skin areas of the same individual.

The Triple Response: With rather firm pressure draw a clean blunt stick across the skin of the forearm or chest, 6 or 7 times. The strokes should be accurately superimposed. The vascular reactions which usually result constitute what has been termed the "Triple Response". The regularity with which the triple response can be obtained depends primarily upon three factors: the sensitiveness of the subject's skin vessels, the region of the body which is stimulated, and the strength of the stimulus.

1. Observe the reddening along the line of stimulation. Time its onset and duration and attempt to explain.
2. If the stimulus has been of sufficient intensity, there will soon appear an area of flushing along each side of the line of stimulation. This is called the "flare" which is due to an axone reflex. By what reasoning would you conclude that it is not due to a spinal reflex? In anesthesia of the skin, the flare fails to develop.

3. On sensitive subjects the tissue in the direct line of stimulation will exhibit swelling and appear edematous within a few minutes after the application of the stimulus. The edematous area is spoken of as a "wheal". Does there seem to be any relation between the intensity of the flare and the appearance of the wheal? The wheal may appear even though the cutaneous nerves have degenerated. To what capillary changes can the formation of the wheal be attributed?

   Time the onset of these three reactions in different individuals, using, as nearly as possible, uniform stimulation. Repeat, varying the strength of the stimulus. Observe the effect of applying cold (cracked ice) and heat (hot water bottle) just prior to stimulation. Repeat, applying cold and heat immediately after stimulation. Explain any effects observed in each instance.

REFERENCES:

The Blood Vessels of the Human Skin and Their Responses, Lewis, 1927

The Anatomy and Physiology of Capillaries, Krogh, 1929

The material on pages 107-108 may be found

TITLE Pharmaceutical Sciences Project Handbook

AUTHOR American Association of Colleges of Pharmacy

PUBLISHER American Pharmaceutical Assoc. Foundation,
Washington, D. C. 1963

PAGE NO. 30-31

PROBLEMS AND QUESTIONS

Name ______________________________

Science IV A Hour ______

Date ______________________________

1. According to Bernouille's Principle

   a. as the volume in a flow-tube increases, the pressure

      ________________________(decreases, increases, remains the same).

   b. Also, assuming mass remains constant, the average velocity of the particles composing the fluid ____________________(decreases, increases, remains the same).

2. a. If the fluid in a flow-tube was such that the average velocity could be kept constant as the pressure was increased, what would have to happen to the density?

   b. What does this imply about the physical nature of the fluid enclosed in the flow-tube?

3. Starting with the equation for , derive the c.g.s. units for the viscosity coefficient.

   Such a unit is called the ____________________.

4. Water is flowing at a speed of 0.60 feet per sec. in a tube of cross-sectional area 0.80 feet^2. By calculating the Reynolds number, determine whether or not the flow is turbulent or laminar.

5. a. Given a tube of internal diameter 1.8 cm, compute the greatest speed at which water can move through this pipe in laminar flow.

   b. Find the corresponding flow-rate.

6. Repeat parts a and b of problem 5 for blood (you will need to look up its coefficient of viscosity).

7. Two flat plates each 6.0 cm^2 in area are separated by a film of oil 0.075 cm. thick. The coefficient of viscosity on this oil is 0.25 m.k.s. units. Compute the speed with which one plate can be moved past the other one (fixed) if a force of 0.040 neuton is applied. What happens to this speed as the moving plate covers an appreciable distance?

8. Find an expression for P, when the flow through a capillary is due to gravity only.

9 a. 5 ml. of water takes 200 secs. to flow through an Ostwald viscosimeter. How long will it take the same amount of ethylene glycol?

b. a fluid of unknown viscosity takes 410 seconds to flow through the same viscosimeter. Compute its coefficient of viscosity.

10. Explain why length and viscosity can be essentially regarded as constant in a closed circulatory system.

11. According to the Poiseuille equation, what must happen to the flow when the arterioles and capillaries of a capillary bed dilate?

12. Given a flow of 4 cubic centimeters per second of a fluid of a viscosity coefficient of 1, through a vessel 1 centimeter in diameter, and 10 centimeters long, calculate the pressure in millimeters.

13. Why is the pressure of a post capillary blood less than that of arterial blood? List contributing factors.

14. In spite of the drop in pressure, blood still returns to the heart. Explain in detail all contributing factors.

15. What was the significance of Loewi's Experiment?

16. Describe the feedback mechanism involved in regulating heart beat.

17. What are some of the functional roles of histamines?

18. Prepare a list of drugs that are known to effect blood pressure and flow throughout the circulatory system. Identify the drug, the site of action, and its specific effects on that site.

IV. Transport of Matter Across Membranes

- A. Passive Transport across membranes in terms of kinetic-molecular theory
  - 1. Osmosis: The movement of water across cell membranes
    - a. Passage of water across articicial membranes
      - 1) semipermeable membranes
      - 2) selectively permeable membranes
    - b. Passage of water across cell membranes
      - 1) hypertonic and hypotonic solutions and their effects on cell volume
        - a) plasmolysis
        - b) deplasmolysis
      - 2) isotonic solutions
    - c. Derivation of an equation for osmotic pressure
      - 1) osmotic pressures of non-electrolytes
        - a) the thistle-tube osmometer

b) difficulties encountered when attempting to measure osmotic pressures inside cells

c) the work of Pfeffer

1) his experiment

2) his data and observations

3) the significance of his findings

PFEFFER'S DATA FOR OSMOTIC PRESSURE AT DIFFERENT CONCENTRATIONS OF SUCROSE

Concentration in Percent	Osmotic Pressure in Atmospheres	Osmotic Pressure Ratio to Concentration
1	0.70	0.7
2	1.34	0.67
4	2.74	0.68
6	4.10	0.68

d) Relationship of osmotic pressure to the Gas Laws

d-1) Van't Hoff's Hypothesis

d-2) Osmotic pressure as measured in terms of Molal Concentration

d-3) Van't Hoff's Law of Osmotic Pressure

3-4) Why the Law is only an approximation

2) The Determination of Osmotic Pressures in Cells

a) Sources of error and their correction when using Van't Hoff's Law for osmotic pressure determination

a-1) osmotic pressures of electrolytes

a-2) Non-solvent volume

a-3) Relative permeability

TABLE: Comparison of Permeabilities of Some Cells in Water

Species	Permeability Constant*
Amoeba proteus	0.026-0.031
Pelomyxa carolinensis	0.023
Fresh water peritrichs	0.125-0.25
Arbacia egg	0.4
Human erythrocyte	3.0

* In cubic microns of water, per square micron of surface area of cell, per atmosphere difference in pressure between the inside and outside of the cell, per minute.

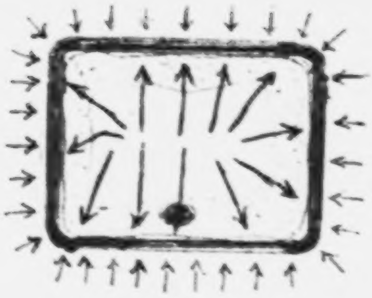
b) Laboratory Investigations:

b-1) The determination of the Osmotic Pressure of Cell Sap

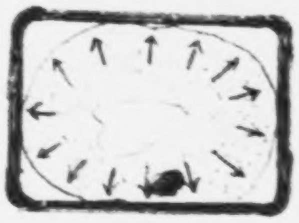
b-2) The determination of the Diffusion Pressure Deficit in plant cells.

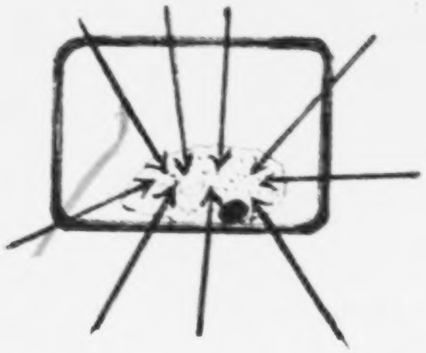
2-a) DPD defined in terms of Osmotic Pressure and Turgor Pressure

TP OP DPD

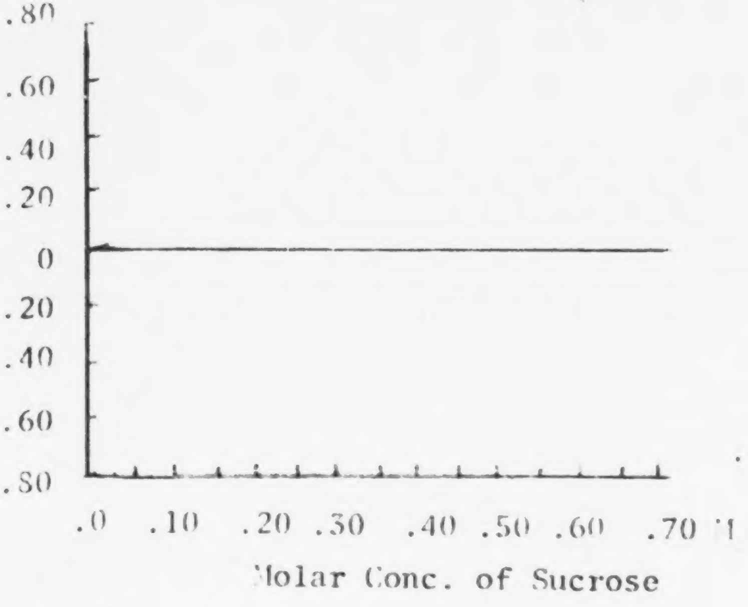


2-b) Theoretical relationship of DPD to Turgor Pressure and Osmotic Pressure

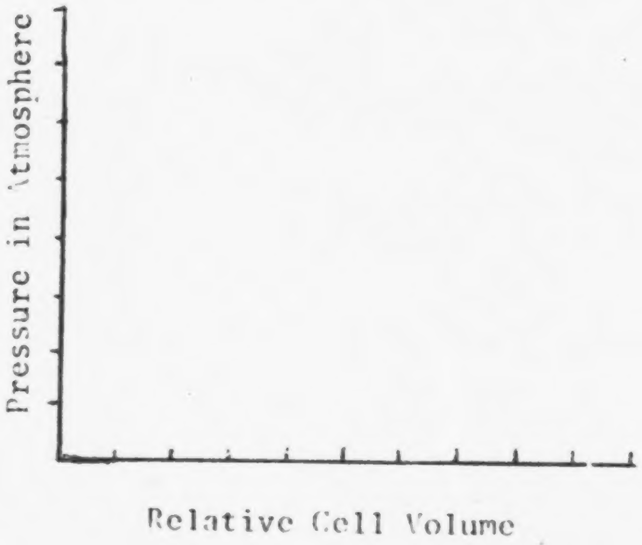




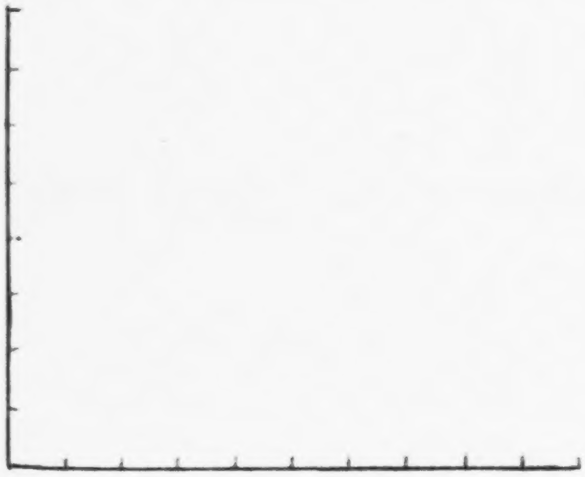
2-c) Interpretation of Curve for Relative cell volume (weight change) against molar concentration



2-d) DPD as determined from a curve for OP and TP against relative cell volume



2-c) The significance of a theoretically possible negative DPD



c) Colligative Properties and the Determination of Osmotic Pressure

The material on page 119 may be found

TITLE Plants In Action: A Laboratory Manual of Plant Physiology

AUTHOR L. Machlis and J. Torrey

PUBLISHER W. H. Freeman and Company, San Francisco, 1956

PAGE NO. 62

Laboratory Report

Name ______________________________

Science IV A Hour _____

Date ______________________________

DETERMINATION OF THE OSMOTIC PRESSURE OF CELL SAP

DATA:

Molar Conc. of Sucrose	Pre-scheduled Removal Time	Number of Cells Plasmolyzed	Number of Cells Unplasmolyzed	Percentage of Cells Plasmolyzed
0.28M				
0.26				
0.24				
0.22				
0.20				
0.18				
0.16				
0.14				

CALCULATIONS:

1. On graph paper, plot the percentage of cells plasmolyzed against the molar concentration of sucrose. Include your plotted curve with the report.

2. By interpolating from your plotted curve, find the solution which caused the plasmolysis of 50 percent of the cells.

3. By applying Van't Hoff's Law, calculate the osmotic pressure of the epidermal cells. Be sure to include the necessary correction factors.

4. Compare the corrected and uncorrected values for osmotic pressure. Are the errors that are introduced by not correcting for the non-solvent volume (and ionization if an electrolytic solution is used) significant?

5. Compare your calculations with those of several other students in your lab. How well do your calculations for O.P. agree? To what factors do you attribute this agreement (or disagreement)?

The material on pages 121-122 may be found

TITLE Plants In Action: A Laboratory Manual of Plant Physiology

AUTHOR L. Machlis and J. Torrey

PUBLISHER W. H. Freeman and Company, San Francisco 1956

PAGE NO. 62-63

Laboratory Report

Name ______________________

Science IV A Hour _____

Date ______________________

DETERMINATION OF THE DIFFUSION PRESSURE DEFICIT OF POTATO CELLS

DATA:

Molar Conc. of Sucrose	Time Schecule		Original Weight	Final Weight	Change in Weight
	Entry	Removal			
Dist. H_2O					
0.15M					
0.20					
0.25					
0.30					
0.35					
0.40					
0.45					
0.50					
0.55					
0.60					

CALCULATIONS AND QUESTIONS:

1. On graph paper, plot the change in weight against the molar concentration of sucrose.

2. By interpolating from your plotted curve, calculate the average osmotic pressure of the cells in the cells in the state they were in just prior to their introduction into the solutions.

3. At this osmotic pressure, calculate the pressure in pounds per square inch with which water presses against the cell membrane. Express this pressure in pounds per square micron.

4. According to the equation, DPD = OP - TP
   a. at what point on the plotted curve would the DPD be maximum?
   b. what would be the turgor pressure at this point?
   c. calculate the DPD at this point.

5. What aspects of the plotted curve suggests that the celluslose fibers of the cell walls may be limiting the cell volume?

6. Calculate the greatest turgor pressure that the cell walls can withstand.

7. Write up a detailed interpretation of what is happening to the cells in terms of how their average ismotic pressure, turgor pressure, and diffusion pressure deficit varies as they change weight. Each section of the curve that is characterized by a different slope, should be considered.

PROBLEMS AND QUESTIONS:

1. For very dilute aqueous solutions, the ideal gas law may be used to express the osmotic pressure of a liquid enclosed in a permeable membrane. Examples include protoplasm enclosed in cells, and plasma enclosed in capillaries. Assuming constant temperature, osmotic pressure is directly proportional to:

2. Water will enter a flow tube with a permeable wall if the fluid enclosed in the tube contains some inpereamble molecules and if:

   a. the fluid pressure > its osmotic pressure

   b. the fluid pressure < its osmotic pressure

   c. the fluid pressure = its osmotic pressure

   d. none of these

3. Why would the exchange of water and other low-energy molecular weight substances between the circulating fluid of the capillaries and the intercellular fluids of the tissues be impossible without the existence of high molecular weight proteins in the circulating fluid?

4. In what ways does the presence of high molecular weight proteins in the blood increase the work that the heart has to do; i.e. what added resistences, introduced by the presence of these proteins, must the heart overcome if sufficient flow and pressure are to be maintained throughout the system?

5. The blood pressure in a certain vessel is measured with a mercury manometer and found to be equivalent to 50 mm Hg. The concentration of solute in the circulating fluid is found to be equivalent to 0.35M. Assume that the following ideal conditions exist:

   a. the vessel wall is permeable to water only and not to the solute particles

   b. the solute is non-electrolytic

   c. the system is at room temperature (22°C) and at sea level.

   d. the fluids surrounding the vessel contain no solute (zero molarity).

   Will water tend to enter or leave through the vessel wall?

   Show calculations which allow you to arrive at an answer.

   1 atmosphere = 760 mm. Hg.

IV A APPENDIX

TABLE OF APPENDICES

Logarithms: A Review . . . . APPENDIX A
Computation With Logarithms . . . . B
Table of Four-Place Logarithms. C
Trigonometric Functions . . . . D
Operation of the Spectronic 20 for Colorimetry . . E
La Pine 203-92 Portable Battery-Operated pH Meter F
Cenco 021662 Electronic pH meter. . . . . G
Acid-Base Indicators . . . . H
Operation of the Ostwald Viscosimeter I
Operation of the Heathkit Oscilloscope - Stimulator (Impscope) . . . . .J
Preparation of Solutions of Known Concentration in Terms of Molarity or Normality . . . . . .K
Preparation of Standard Buffers L
Procedures for Obtaining Titration Curves . . . . .M
Table of Conjugate Acid-Base Pairs Including Acid-Ionization Constants . . . . .N
Heats of Combustion of Some Common Organic Compound in Calories per Mole . . . . .O
Physical Quantities and Units . . . . .P
Physical Constants . . . . Q
Conversion Factors . . . . R
Periodic Chart of the Elements . . . . S

APPENDIX A

LOGARITHMS: A REVIEW

A logarithm is an exponent, or power, to which some base is raised. If b is any positive number, different from 1, and $b^n = x$, then the exponent n is called the logarithm of x to the base b: $\log_b x = n$

Examples are as follows:

$\log_3 9 = 2$	read	"logarithm of	9	to the base	3	is	2"	because	$3^2 = 9$
$\log_2 2 = 1$	"	"	" 2	" " "	2	is	1	"	$2^1 = 2$
$\log_2 8 = 3$	"	"	" 8	" " "	2	"	3	"	$2^3 = 8$
$\log_2 16 = 4$	"	"	" 16	" " "	2	"	4	"	$2^4 = 16$
$\log_{10} 100 = 2$	"	"	" 100	" "	10	"	2	"	$10^2 = 100$
$\log_{10} 0.001 = -3$			.001	" "	10	"	-3	"	$10^{-3} = .001$
$\log_b x = n$			x		b	"	n		$b^n = x$

Tables for $\log_2$ are not readily found, but tables for logarithms to the base 10 ($\log_{10}$) are quite commonly used. The logarithms based upon 10 are called common logarithms. Conversion from $\log_{10}$ to logarithms to some other base is possible only after we become familiar with common logarithms.

The following is a simple table of common logarithms:

x:	.0001	.001	.01	.1	1	10	100	1000	10000
log x:	-4	-3	-2	-1	0	1	2	3	4

but logarithms may not always be whole numbers, for example, consider the number 382. Because it is between 100 and 1000, its log must be between 2 and 3 since $10^2 = 100$ and $10^3 = 1000$

$$\log 382 = 2.5821$$

or in exponential form,

$$10^{2.5821} = 382$$

Now how was the logarithm of 382 determined?

First of all, note any logarithm consists of 2 parts;

an integer, called the characteristic, and
a decimal, called the mantissa

2.5821
↑ ↑ mantissa
characteristic

The characteristic is found by noting the position of the number's decimal point. For this, the following three rules apply:

1. If the decimal point of the number immediately follows its first digit, the characteristic of the logarithm of that number is zero. Note that the logarithm of any number from 1 to 10, but not including 10, has as its characteristic, zero.
2. If the decimal point appears after the second digit, the characteristic of its logarithm is 1, if after 3 digits, it is 2; if after 4 digits, it is 3, etc. This is why the characteristic of log 382 is 2.
3. If the decimal point appears immediately before the first non-zero digit, the characteristic of its logarithm is -1, sometimes denoted

as $\bar{1}$; if there is one zero between the decimal point and the first digit, the characteristic is $\bar{2}$, etc.

Example: $\log .008 = -3 + .9031$

or $\bar{3}.9031$

or $10-3 + .9031-10 = 7.9031-10 = -2.0969$

Note that the characteristic of $\log_{10} 0.008$ must be between -3 and -2 since $\log_{10} 0.001 = -3$ and $\log_{10} 0.010 = -2$ $\text{Log}_{10} 0.008 = -3 + .9031$ does not mean that it equals -3.9031 since the latter would turn out to be between -3 and -4 instead of between -3 and -2.

SAMPLE PROBLEMS:

Find the characteristic of the logarithm for each of the following numbers.

1) 1000

2) 159

3) .5230

4) 5,230,000

5) .00007

6) 6.2380

7) .00523

8) 43.4

Finding the mantissa of the logarithm of a number:

Going back to our original example, log 382 = 2.5821

It is clear that the logarithm of 382 must be between 2 and 3 since 382 is between $10^2 = 100$ and $10^3 = 1000$. Neither the digit 2 nor the digit 3 can alone express the logarithm to the base 10 of 382. Such a logarithm has to be a number somewhere between 2 and 3 and is expressed as the decimal .5821. This decimal is called the mantissa of the logarithm and there are two ways of finding it.

Tables can be used to find the mantissa of a common logarithm. In the left hand column, find the first two digits of the number for which you want to find the mantissa. Then find the 3rd digit of the number in the top horizontal column. The mantissa is then located at the junction of the two rows you have found.

Thus: $\log 382 = 2.5821$

or in exponential terms: $10^{2.5821} = 382$

If there is a fourth significant digit in the number whose logarithm is being looked for, round off to three significant digits or use tables for 5-place logarithms.

SAMPLE PROBLEMS:

9) log 274

10) log 0.00458

11) log 1,378,000

12) log 124

13) log 0.0124

14) log 39.6

15) log .0435

16) log 0.000346

17) log 360

18) log .005

The tables can also be used to convert a logarithm into its original number, or antilogarithm.

Example: Find the antilogarithm of $\bar{2}.6812$

(that is, find the number whose logarithm is $\bar{2}.6812$).

The mantissa, 0.6812 represents the digits 480 on the log table. Since the characteristic is $\bar{2}$, the antilogarithm of $\bar{2}.6812$ is .0480, that is, $10^{\bar{2}.6812} = 0.0480$.

SAMPLE PROBLEMS:

19) antilog 1.5211

20) antilog 9.5211-10

21) antilog 1.6972

22) antilog $\bar{2}.3729$

23) antilog 9.7364-10

24) antilog 3.9717

25) antilog $\bar{3}.9717$

The other way to find the logarithm of a number is with the D-L combination of scales on the slide rule.

To find the logarithm of a number, set the D and L scales in exact register with one another, locate the significant digits on the D scale and the required logarithm will be found by use of the cursor in register on the L scale. The characteristic of the logarithm is found from the position of the decimal point in the same way as it is determined when a log table is used.

To find the number when given its logarithm, locate the mantissa of the logarithm upon the L scale and read off the significant digits of the number in register on the D scale. The decimal point for the number is fixed by the characteristic of the given logarithm in the usual manner.

APPENDIX B

COMPUTATION WITH LOGARITHMS

Once the use of the tables in finding logarithms and antilogarithms has been mastered, one is now ready to begin using logarithms as tools for computation. Such work is made simple on consideration of the meaning of each of the following theorems:

Theorem 1. $\log_b (xw) = \log_b x + \log_b w$

Theorem 2. $\log_b (x/w) = \log_b x - \log_b w$

Theorem 3. $\log_b (x^r) = r \log_b x$

These theorems are simply translations from the language of exponents into the language of logarithms. The corresponding laws for exponents are as follows:

$$b^y \; b^w = b^{y+u}$$
$$b^y/b^w = b^{y-u}$$
$$(b^y)^r = b^{yr}$$

Proofs of the three theorems will not be given here but can be found in any math book on the subject.

1st EXAMPLE;

Calculate $\dfrac{(3.21) \quad (52.8)}{294}$

Call the result x. Then by theorems 1 and 2 above,

$$\log x = \log \frac{(3.21)\ (52.8)}{294} = \log 3.21 + \log 52.8 - \log 294$$

NOW

$\log 3.21 = 0.5065$

$\log 52.8 = \underline{1.7226}$

$\log 3.21 + \log 52.8 = 2.2291$

$\log 294 = \underline{2.4683}$ to subtract

$\log x = -0.2392$

A negative exponent can be converted to a logarithm with a negative characteristic and a positive mantissa in the following manner:

$y - 10 = -0.2392$ where $y-10 = \log x$

$y = -0.2392 + 10$

$y = 9.7608$

thus: $\log x = 9.7608-10$ or $\bar{1}.7608$

hence $x = \text{antilog } \bar{1}.7608 = 0.576$

By using logarithms, the problem has been done in a much shorter time than it would have been by straightforward arithmetic. The use of logarithms shortens computation time because the cumbersome, time-consuming operations of multiplication, division and root-extraction are replaced by simpler operations of adding logarithms for multiplication, subtracting them for division and dividing them by the root-index for root-extraction. In so doing, every positive number is represented as a power of 10:

$3.21 = 10^{0.5065}$ $\qquad 52.8 = 1.7226$ $\qquad 294 = 10^{2.4683}$

$$\frac{(3.21)\ (52.8)}{294} = \frac{(10^{0.5065})\ (10^{1.7226})}{10^{2.4683}} = 10^{0.5065\ +\ 1.7226\ -\ 2.4683}$$

$$= 10^{-0.2392} = 10^{9.7608-10} \text{ or } 10^{\bar{1}.7608} = 0.576$$

Note that this problem could be done even faster on the slide-rule, but in multiplying and dividing on the slide-rule, one is still carrying out the same operations since the C and D scales are scales of logarithms.

Consider the next example (#2)

Find $100\ (1.02)^{64}$, letting the result be called x.

Then by theorems 1 and 3:

$$\log x = \log 100 + 64 \log 1.02$$

$$= 2 + 64\ (0.0086) = 2.5504$$

Hence, $x = \text{antilog } 2.5504 = 355$

If the above problem is attempted with the slide-rule alone, the value of using logarithms for computation becomes quickly appreciated.

3rd EXAMPLE

Find $\sqrt[4]{329}$ Let x be the result.

$x = \sqrt[4]{329} = 329^{1/4}$

By theorem 3:

$\log x = \frac{1}{4} \log 329 = \frac{1}{4}\ (2.5172) = 0.6293$

hence $x = \text{antilog } 0.6293 = 4.26$

SAMPLE PROBLEMS:

Evaluate by means of logarithms:

1. $\dfrac{(29.7)\ (3.4)}{572}$

2. $\dfrac{(492)\ (6.82)^2}{(59)^3}$

3. $\sqrt[3]{79200}$

4. $\sqrt[5]{0.00759}$

5. $321\ (1.04)^{19}$

FOUR-PLACE LOGARITHMS

N	0	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996
	0	1	2	3	4	5	6	7	8	9

Published and Copyright 1956 by The Welch Scientific Company, 7300 North Linder Avenue, Skokie, Illinois 60076

Catalog No. 592

TRIGONOMETRIC FUNCTIONS

SIN

ANG.	0'	12'	24'	36'	48'	60'	
0	.0000	.0035	.0070	.0105	.0140	.0175	89
1	.0175	.0209	.0244	.0279	.0314	.0349	88
2	.0349	.0384	.0419	.0454	.0488	.0523	87
3	.0523	.0558	.0593	.0628	.0663	.0698	86
4	.0698	.0732	.0767	.0802	.0837	.0872	85
5	.0872	.0906	.0941	.0976	.1011	.1045	84
6	.1045	.1080	.1115	.1149	.1184	.1219	83
7	.1219	.1253	.1288	.1323	.1357	.1392	82
8	.1392	.1426	.1461	.1495	.1530	.1564	81
9	.1564	.1599	.1633	.1668	.1702	.1736	80
10	.1736	.1771	.1805	.1840	.1874	.1908	79
11	.1908	.1942	.1977	.2011	.2045	.2079	78
12	.2079	.2113	.2147	.2181	.2215	.2250	77
13	.2250	.2284	.2317	.2351	.2385	.2419	76
14	.2419	.2453	.2487	.2521	.2554	.2588	75
15	.2588	.2622	.2656	.2689	.2723	.2756	74
16	.2756	.2790	.2823	.2857	.2890	.2924	73
17	.2924	.2957	.2990	.3024	.3057	.3090	72
18	.3090	.3123	.3156	.3190	.3223	.3256	71
19	.3256	.3289	.3322	.3355	.3387	.3420	70
20	.3420	.3453	.3486	.3518	.3551	.3584	69
21	.3584	.3616	.3649	.3681	.3714	.3746	68
22	.3746	.3778	.3811	.3843	.3875	.3907	67
23	.3907	.3939	.3971	.4003	.4035	.4067	66
24	.4067	.4099	.4131	.4163	.4195	.4226	65
25	.4226	.4258	.4289	.4321	.4352	.4384	64
26	.4384	.4415	.4446	.4478	.4509	.4540	63
27	.4540	.4571	.4602	.4633	.4664	.4695	62
28	.4695	.4726	.4756	.4787	.4818	.4848	61
29	.4848	.4879	.4909	.4939	.4970	.5000	60
30	.5000	.5030	.5060	.5090	.5120	.5150	59
31	.5150	.5180	.5210	.5240	.5270	.5299	58
32	.5299	.5329	.5358	.5388	.5417	.5446	57
33	.5446	.5476	.5505	.5534	.5563	.5592	56
34	.5592	.5621	.5650	.5678	.5707	.5736	55
35	.5736	.5764	.5793	.5821	.5850	.5878	54
36	.5878	.5906	.5934	.5962	.5990	.6018	53
37	.6018	.6046	.6074	.6101	.6129	.6157	52
38	.6157	.6184	.6211	.6239	.6266	.6293	51
39	.6293	.6320	.6347	.6374	.6401	.6428	50
40	.6428	.6455	.6481	.6508	.6534	.6561	49
41	.6561	.6587	.6613	.6639	.6665	.6691	48
42	.6691	.6717	.6743	.6769	.6794	.6820	47
43	.6820	.6845	.6871	.6896	.6921	.6947	46
44	.6947	.6972	.6997	.7022	.7046	.7071	45
45	.7071	.7096	.7120	.7145	.7169	.7193	44
	60'	48'	36'	24'	12'	0'	ANG.

COS

SIN

ANG.	0'	12'	24'	36'	48'	60'	
46	.7193	.7218	.7242	.7266	.7290	.7314	43
47	.7314	.7337	.7361	.7385	.7408	.7431	42
48	.7431	.7455	.7478	.7501	.7524	.7547	41
49	.7547	.7570	.7593	.7615	.7638	.7660	40
50	.7660	.7683	.7705	.7727	.7749	.7771	39
51	.7771	.7793	.7815	.7837	.7859	.7880	38
52	.7880	.7902	.7923	.7944	.7965	.7986	37
53	.7986	.8007	.8028	.8049	.8070	.8090	36
54	.8090	.8111	.8131	.8151	.8171	.8192	35
55	.8192	.8211	.8231	.8251	.8271	.8290	34
56	.8290	.8310	.8329	.8348	.8368	.8387	33
57	.8387	.8406	.8425	.8443	.8462	.8480	32
58	.8480	.8499	.8517	.8536	.8554	.8572	31
59	.8572	.8590	.8607	.8625	.8643	.8660	30
60	.8660	.8678	.8695	.8712	.8729	.8746	29
61	.8746	.8763	.8780	.8796	.8813	.8829	28
62	.8829	.8846	.8862	.8878	.8894	.8910	27
63	.8910	.8926	.8942	.8957	.8973	.8988	26
64	.8988	.9003	.9018	.9033	.9048	.9063	25
65	.9063	.9078	.9092	.9107	.9121	.9135	24
66	.9135	.9150	.9164	.9178	.9191	.9205	23
67	.9205	.9219	.9232	.9245	.9259	.9272	22
68	.9272	.9285	.9298	.9311	.9323	.9336	21
69	.9336	.9348	.9361	.9373	.9385	.9397	20
70	.9397	.9409	.9421	.9432	.9444	.9455	19
71	.9455	.9466	.9478	.9489	.9500	.9511	18
72	.9511	.9521	.9532	.9542	.9553	.9563	17
73	.9563	.9573	.9583	.9593	.9603	.9613	16
74	.9613	.9622	.9632	.9641	.9650	.9659	15
75	.9659	.9668	.9677	.9686	.9694	.9703	14
76	.9703	.9711	.9720	.9728	.9736	.9744	13
77	.9744	.9751	.9759	.9767	.9774	.9781	12
78	.9781	.9789	.9796	.9803	.9810	.9816	11
79	[illegible]	.9823	.9829	.9836	.9842	.9848	10
80	.9848	.9854	.9860	.9866	.9871	.9877	9
81	.9877	.9882	.9888	.9893	.9898	.9903	8
82	[illegible]	[illegible]	[illegible]	.9917	[illegible]	[illegible]	7
83	.9925	.9930	.9934	.9938	.9942	.9945	6
84	.9945	.9949	.9952	.9956	.9959	.9962	5
85	.9962	.9965	.9968	.9971	.9973	.9976	4
86	.9976	.9978	.9980	.9982	.9984	.9986	3
87	.9986	.9988	.9990	.9991	.9993	.9994	2
88	.9994	.9995	.9996	.9997	.9998	.9998	1
89	.9998	.9999	.9999	1.000	1.000	1.000	0
90	1.000						
	60'	48'	36'	24'	12'	0'	ANG.

COS

TAN

ANG.	0'	12'	24'	36'	48'	60'	
0	.0000	.0035	.0070	.0105	.0140	.0175	89
1	.0175	.0209	.0244	.0279	.0314	.0349	88
2	.0349	.0384	.0419	.0454	.0489	.0524	87
3	.0524	.0559	.0594	.0629	.0664	.0699	86
4	.0699	.0734	.0769	.0805	.0840	.0875	85
5	.0875	.0910	.0945	.0981	.1016	.1051	84
6	.1051	.1086	.1122	.1157	.1192	.1228	83
7	.1228	.1263	.1299	.1334	.1370	.1405	82
8	.1405	.1441	.1477	.1512	.1548	.1584	81
9	.1584	.1620	.1655	.1691	.1727	.1763	80
10	.1763	.1799	.1835	.1871	.1908	.1944	79
11	.1944	.1980	.2016	.2053	.2089	.2126	78
12	.2126	.2162	.2199	.2235	.2272	.2309	77
13	.2309	.2345	.2382	.2419	.2456	.2493	76
14	.2493	.2530	.2568	.2605	.2642	.2679	75
15	.2679	.2717	.2754	.2792	.2830	.2867	74
16	.2867	.2905	.2943	.2981	.3019	.3057	73
17	.3057	.3096	.3134	.3172	.3211	.3249	72
18	.3249	.3288	.3327	.3365	.3404	.3443	71
19	.3443	.3482	.3522	.3561	.3600	.3640	70
20	.3640	.3679	.3719	.3759	.3799	.3839	69
21	.3839	.3879	.3919	.3959	.4000	.4040	68
22	.4040	.4081	.4122	.4163	.4204	.4245	67
23	.4245	.4286	.4327	.4369	.4411	.4452	66
24	.4452	.4494	.4536	.4578	.4621	.4663	65
25	.4663	.4706	.4748	.4791	.4834	.4877	64
26	.4877	.4921	.4964	.5008	.5051	.5095	63
27	.5095	.5139	.5184	.5228	.5272	.5317	62
28	.5317	.5362	.5407	.5452	.5498	.5543	61
29	.5543	.5589	.5635	.5681	.5727	.5774	60
30	.5774	.5820	.5867	.5914	.5961	.6009	59
31	.6009	.6056	.6104	.6152	.6200	.6249	58
32	.6249	.6297	.6346	.6395	.6445	.6494	57
33	.6494	.6544	.6594	.6644	.6694	.6745	56
34	.6745	.6796	.6847	.6899	.6950	.7002	55
35	.7002	.7054	.7107	.7159	.7212	.7265	54
36	.7265	.7319	.7373	.7427	.7481	.7536	53
37	.7536	.7590	.7646	.7701	.7757	.7813	52
38	.7813	.7869	.7926	.7983	.8040	.8098	51
39	.8098	.8156	.8214	.8273	.8332	.8391	50
40	.8391	.8451	.8511	.8571	.8632	.8693	49
41	.8693	.8754	.8816	.8878	.8941	.9004	48
42	.9004	.9067	.9131	.9195	.9260	.9325	47
43	.9325	.9391	.9457	.9523	.9590	.9657	46
44	.9657	.9725	.9793	.9861	.9930	1.000	45
45	1.000	1.007	1.014	1.021	1.028	1.035	44
	60'	48'	36'	24'	12'	0'	ANG.

COT

TAN

ANG.	0'	12'	24'	36'	48'	60'	
46	1.036	1.043	1.050	1.058	1.065	1.072	43
47	1.072	1.080	1.088	1.095	1.103	1.111	42
48	1.111	1.118	1.126	1.134	1.142	1.150	41
49	1.150	1.159	1.167	1.175	1.183	1.192	40
50	1.192	1.200	1.209	1.217	1.226	1.235	39
51	1.235	1.244	1.253	1.262	1.271	1.280	38
52	1.280	1.289	1.299	1.308	1.318	1.327	37
53	1.327	1.337	1.347	1.356	1.366	1.376	36
54	1.376	1.387	1.397	1.407	1.418	1.428	35
55	1.428	1.439	1.450	1.461	1.472	1.483	34
56	1.483	1.494	1.505	1.517	1.528	1.540	33
57	1.540	1.552	1.564	1.576	1.588	1.600	32
58	1.600	1.613	1.626	1.638	1.651	1.664	31
59	1.664	1.678	1.691	1.705	1.718	1.732	30
60	1.732	1.746	1.760	1.775	1.789	1.804	29
61	1.804	1.819	1.834	1.850	1.865	1.881	28
62	1.881	1.897	1.913	1.929	1.946	1.963	27
63	1.963	1.980	1.997	2.015	2.032	2.050	26
64	2.050	2.069	2.087	2.106	2.125	2.145	25
65	2.145	2.164	2.184	2.205	2.225	2.246	24
66	2.246	2.267	2.289	2.311	2.333	2.356	23
67	2.356	2.379	2.402	2.426	2.450	2.475	22
68	2.475	2.500	2.526	2.552	2.578	2.605	21
69	2.605	2.633	2.661	2.689	2.718	2.748	20
70	2.748	2.778	2.808	2.840	2.872	2.904	19
71	2.904	2.937	2.971	3.006	3.042	3.078	18
72	3.078	3.115	3.152	3.191	3.231	3.271	17
73	3.271	3.312	3.354	3.398	3.442	3.487	16
74	3.487	3.534	3.582	3.630	3.681	3.732	15
75	3.732	3.785	3.839	3.895	3.952	4.011	14
76	4.011	4.071	4.134	4.198	4.264	4.332	13
77	4.332	4.402	4.474	4.548	4.625	4.705	12
78	4.705	4.787	4.872	4.959	5.050	5.145	11
79	5.145	5.242	5.344	5.449	5.558	5.671	10
80	5.671	5.789	5.912	6.041	6.174	6.314	9
81	6.314	6.460	6.612	6.772	6.940	7.115	8
82	7.115	7.300	7.495	7.700	7.916	8.144	7
83	8.144	8.386	8.643	8.915	9.205	9.514	6
84	9.514	9.845	10.20	10.58	10.99	11.43	5
85	11.43	11.91	12.43	13.00	13.62	14.30	4
86	14.30	15.06	15.89	16.83	17.89	19.08	3
87	19.08	20.45	22.02	23.86	26.03	28.64	2
88	28.64	31.82	35.80	40.92	47.74	57.29	1
89	57.29	71.62	95.49	143.2	286.5		0
90							
	60'	48'	36'	24'	12'	0'	ANG.

COT

Published and Copyright 1956 by The Welch Scientific Company, 7300 North Linder Avenue, Skokie, Illinois 60076

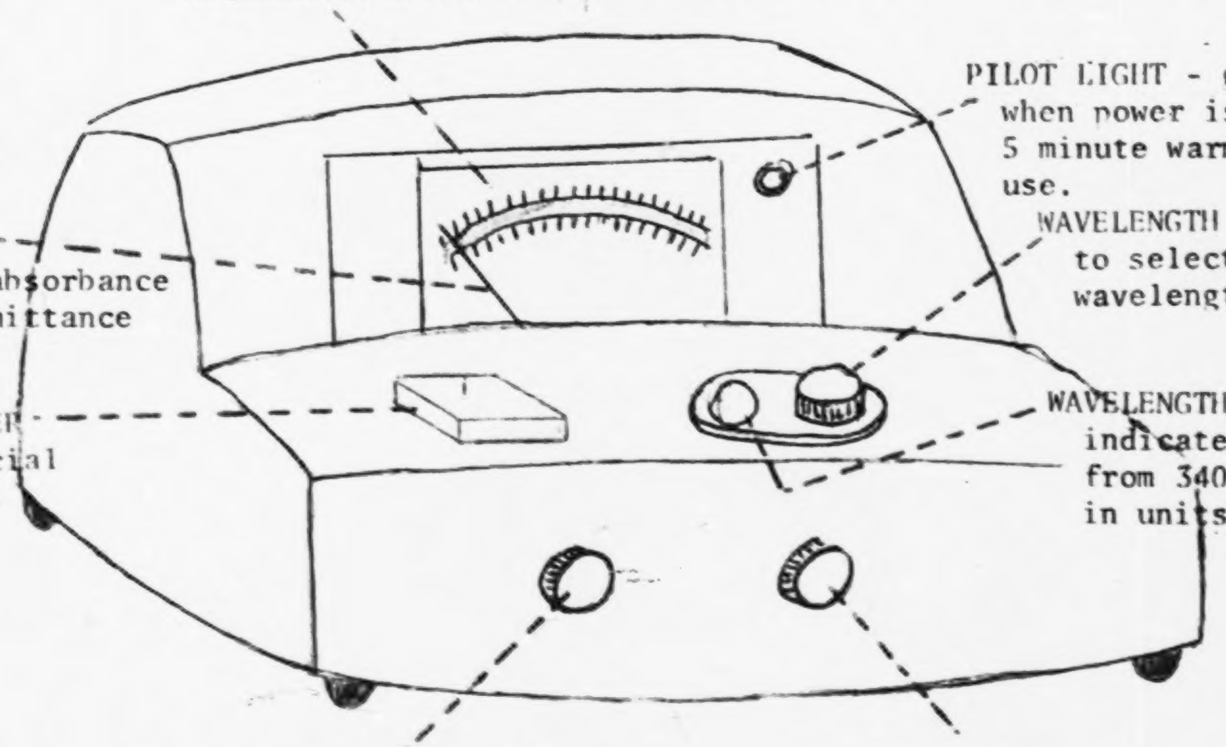
Catalog No. 592

OPERATION OF SPECTRONIC 20 FOR COLORIMETRY

1. Rotate the wavelength control until desired wavelength is indicated by the wavelength scale.
2. Turn on power switch, also called zero control, clockwise; the pilot light will glow. Allow five minute warm-up. With zero control bring meter needle to "0" on the Percent Transmittance scale of meter.
3. Insert test tube 1/2 full of distilled water into sample holder. Close adapter cover. Rotate Light Control until meter reads "100" on the Percent Transmittance scale.
4. Insert unknown sample in place of water or standard and read percent transmittance directly from meter.
5. It is best to turn the light control counterclockwise before changing to another wavelength.

IMPORTANT:

It is necessary to repeat step 3 each time a different wavelength is used. When operating on a fixed wavelength check periodically for meter "drift" from 100%.



METER SCALES:
Transmittance scale from 0 to 100% (black engravings at top)
Absorbance scale from 0 to infinity (red engravings at bottom)

PILOT LIGHT - glows red when power is on. Allow 5 minute warm-up before use.

METER NEEDLE - indicates absorbance &/or transmittance readings.

WAVELENGTH CONTROL - to select desired wavelength.

SAMPLE HOLDER - takes special test tube.

WAVELENGTH SCALE - indicates wavelengths from 340 to 960 $m\mu$ in units of 5 $m\mu$

POWER SWITCH (ZERO CONTROL) turns on instrument and permits zeroing of meter needle on % transmittance scale.

LIGHT CONTROL - for setting meter needle to read 100% transmittance for the solvent being used.

APPENDIX F

LA PINE 203-92 PORTABLE BATTERY OPERATED pH METER

BATTERY CHECK

1. Set the temperature COMPENSATOR KNOB to BATTERY CHECK.
2. Turn the FUNCTION SWITCH to ON.
3. Turn the ASYMMETRY CONTROL KNOB until the black meter needle reads 7.
4. Turn the FUNCTION SWITCH back to BATTERY CHECK. As long as the black meter needle is on or to the right of the red battery check line on the meter scale panel the batteries are good. If the needle moves to the left of the battery check line replace one or the other or both dry cells and perform the battery check routine again until a good reading is obtained.

MOUNTING THE ELECTRODE

Position the electrode support arm by loosening the locking nut, moving the arm to the desired position, and tightening the nut. (When storing the pH meter loosen the nut and move the arm counterclockwise toward the electrode connection.)

Connect the combination electrode to the instrument by slipping the connector on the electrode lead over the connector on the case and turning it clockwise until it locks. To attach the electrode clamp slip it over the lead then slide it down over the upper (smaller diameter) plastic head of the electrode. Do not attempt to snap the electrode holder onto the electrode.

Keep the electrode filled with electrode filling solution to a point about 1/4" below the vent hole when the electrode is in a vertical position. To fill the electrode remove the vent plug and add electrode filling solution with the dropping pipet. Replace the vent plug until use.

STANDARDIZATION

When standardizing the pH meter use a buffer solution close to the pH of the sample, preferably within 2 pH units of the sample pH. The buffer solution should be at or near the temperature of the sample solution.

1. Turn the FUNCTION SWITCH to ON.
2. Set the temperature COMPENSATOR to the temperature of the buffer solution.

3. Open the vent hole on the electrode. The vent hole should always be open when the electrode is being used. Do not lose the rubber plug as it must be replaced when the electrode is not in use.

4. Rinse the end of the electrode with distilled water.

5. Immerse the electrode in the buffer solution.

6. Turn the FUNCTION SWITCH to READ.

7. Using the ASYMMETRY CONTROL set the black meter needle to the pH value of the buffer solution.

8. Turn the FUNCTION SWITCH back to ON.

9. The black meter needle will move off the value at which it was set by the asymmetry control. Set the red dead pointer to coincide with the black meter needle. As long as the pH metter is not turned OFF it will not be necessary to restandardize with the buffer solution. Simply set the function switch to ON and match the black meter needle to the red pointer using the asymmetry control.

10. Go to measurements procedure.

MEASUREMENT

pH MEASUREMENT

1. Clean the electrode with distilled water.

2. Immerse the electrode in the sample solution.

3. Turn the FUNCTION SWITCH to READ and read pH value. Then return to ON position when finished.

MILLIVOLT MEASUREMENT

1. The 203-95 platinum-calomel combination electrode must be used to make millivolt measurements. The 203-94 combination electrode furnished with the instrument is not suitable.

2. Clean the electrode with distilled water and immerse it in the sample solution.

3. Turn the temperature COMPENSATOR KNOB counterclockwise until it operates the snap switch and points to MILLIVOLTS.

4. Turn the FUNCTION SWITCH to ON.

5. Using the ASYMMETRY CONTROL set the black meter needle to read 0 millivolts.

6. Turn the FUNCTION SWITCH to READ and read millivolt value.

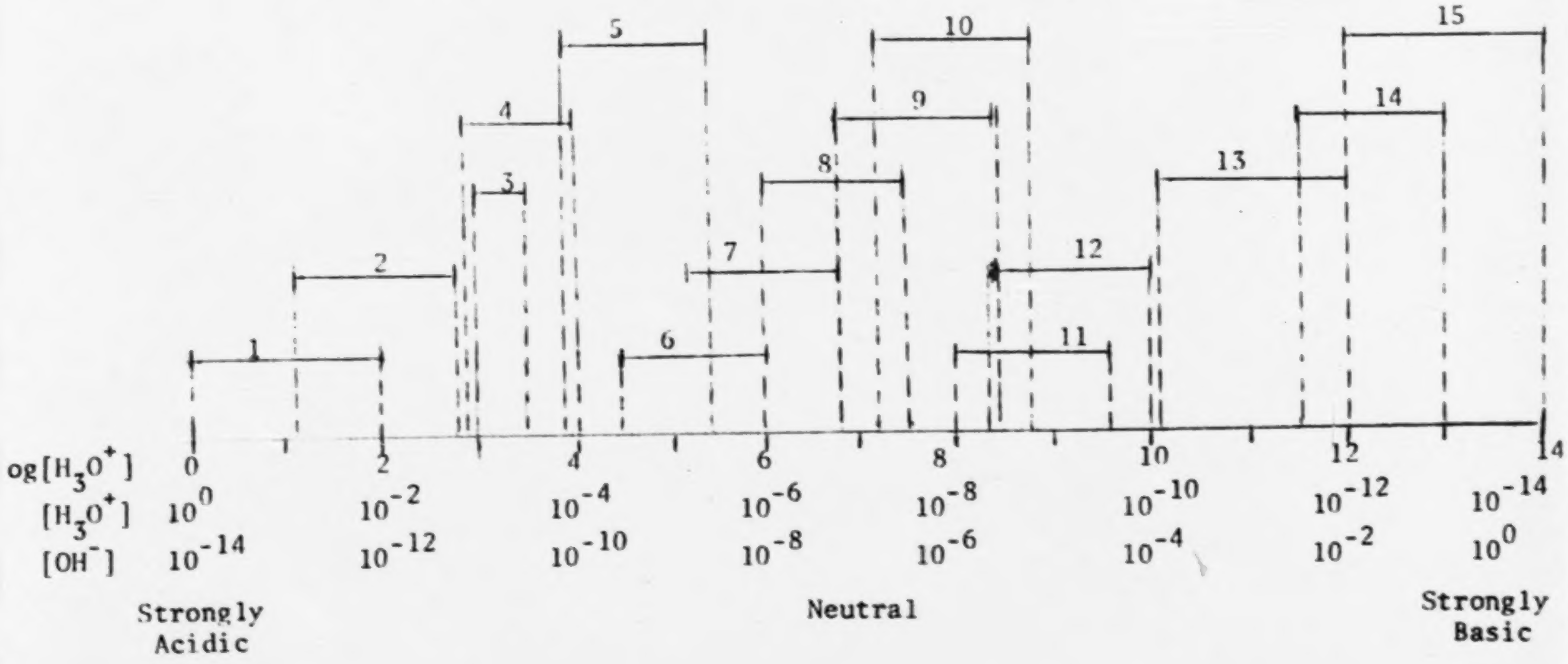
APPENDIX G

CENCO 021662 Electronic pH Meter

APPENDIX H

ACID - BASE INDICATORS

Diagram No.	Indicator	Color Change with Increasing pH	pH Range
1.	Methyl Violet		0 - 2.0
2.	Thymol Blue	red to yellow	1.2 - 2.8
3.	Bromphenol Blue	yellow to blue	3.0 - 3.6
4.	Methyl Orange	red to yellow	2.9 - 4.0
5.	Bromcresol Green	yellow to blue	3.8 - 5.4
6.	Methyl Red	red to yellow	4.4 - 6.0
7.	Bromphenol Red		5.2 - 6.8
8.	Bromthymol Blue	yellow to blue	6.0 - 7.6
9.	Phenol Red	yellow to red	6.8 - 8.4
10.	Cresol Red		7.2 - 8.8
11.	Thymol Blue		8.0 - 9.6
12.	Phenolphthalein	colorless to red	8.3 - 10.0
13.	Alazarin Yellow R.	yellow to violet	10.1 - 12.0
14.	Indigo Carmine	blue to yellow	11.6 - 13.0
15.	1, 3, 5 - Trinitrobenzene	colorless to orange	12.0 - 14.0



OPERATION OF THE OSTWALD VISCOSIMETER

DESCRIPTION:

Since viscosity is a measure of resistence to flow, the viscosity of a given fluid will be proportional to the time it takes the fluid to flow through a tube of sufficiently small diameter. Since viscosity varies directly with temperature, some provision must be made to keep the temperature of the fluid constant during the flow.

A U-shaped tube suspended vertically in a constant-temperature water-bath could serve as a primitive viscosimeter. By introducing a fluid into one of the arms, measuring the time it takes the fluid to reach the bottom of the tube and comparing this time to those for other fluids, one could obtain its relative viscosity. The Ostwald viscosimeter is a more refined version which permits us to determine what is known as the kinematic viscosity. By referring to the figure shown in this appendix, it can be seen that the Ostwald viscosimeter is a U-shaped tube which contains a section of capillary in one of its arms and the appropriate reservoirs for delivering and receiving a measured volume of fluid to and from the capillary.

The various dimensions of the Ostwald viscosimeter and their spacing relative to one another are such as to correct for a number of errors that otherwise would have to be taken into consideration in viscosity determinations. What the sources of these errors are and how the design of the viscosimeter corrects for them is quite complex. Here we shall only go into the theory governing its use.

THEORY:

Since we are dealing with a case of viscous flow through a capillary, Poiseuille's equation gives the quantity V, which flows through during time t:

$$V = \frac{\pi P R^4 t}{8 \eta L}$$

An expression for P, the pressure exerted by the liquid due to its weight is obtained as follows:

$$P = {}^{F}/_{A} = {}^{mg}/_{A}$$ where g is acceleration due to gravity acting on the column of liquid.

Substituting $D_m V$ for m:

$$P = \frac{D_m V g}{A}$$ where D_m = mass density

Substituting Ah for V and then cancelling the A's:

$$P = \frac{D_m Ahg}{A} = D_m hg$$

where h = the mean level difference of the liquid (variations in the level difference throughout the running happen to have no effect on the measurement.)

This value for P is now substituted into Poiseuille's equation:

$$V = \frac{\pi D_m hgR^4 t}{8 \eta L}$$

where g, R and L are constant V is a fixed volume and h is calculated as the mean level difference.

Rearranging the latter so as to collect all constant values on one side, an expression can be obtained for what is defined as KINEMATIC VISCOSITY:

$$\eta/D_m = \left(\frac{\pi hgR^4}{8VL}\right) t$$

Since everything appearing in the brackets is constant:

$$\eta/D_m = kt$$

where k is in $cm^2/_{sec^2}$

$$\left(\frac{hgR^4}{VL} = \frac{cm}{cm^3} \cdot \frac{cm}{cm^2} \cdot \frac{cm^4}{cm} = cm^2/_{sec^2}\right)$$

Hence a measurement of the time of emptying the upper reservoir of the volume V, determines the kinematic viscosity η/D_m, once k is known.

The constant k can be established for a particular viscometer by measuring the flow-time of water or some other liquid of known viscosity and density:

$$k_{H_2O} = \eta/_{tD_m} = \frac{0.0089 \text{ poises}}{\text{t in secs} \cdot 1 \text{ gram}/_{cm^3}}$$

Then to obtain η:

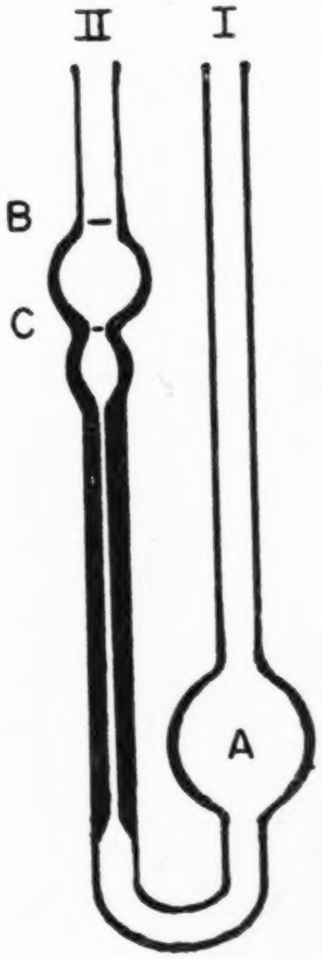
$$\eta = ktD_m$$

where η is in poises

$$\left(cm^2/_{sec^2} \cdot \frac{sec}{1} \cdot \frac{gram}{cm^3} = \frac{gram}{sec\text{-}cm} = poise\right)$$

PROCEDURE FOR DETERMINING VISCOSITIES:

The following procedure is run first with a volume of standard in order to determine k, and then with an equivalent volume of fluid whose viscosity is to be determined.



1. A volume of fluid is measured out in introduced through tube I to bulb A.

2. The viscosimeter with the sample inside is clamped vertically to a ringstand and immersed in a constant temperature water bath until the desired temperature is obtained.

3. The fluid is raised up into tube II by suction until the bottom of its upper meniscus is just on the B mark.

4. Removal of suction by releasing the index finger from tube I allows the fluid to begin its flow through the capillary and the time required for the meniscus to move from the B mark to the C mark is measured in seconds with a stop-watch.

5. The constant k is determined by measuring the time it takes for a given volume of standard to run through the capillary and then plugging this value into the following equation:

$$k = \frac{\eta_{H_2O \text{ at } 25^\circ C}}{tD_m}$$

The viscosity of an equivalent volume of unknown fluid is then given by:

$$\eta = ktD_m$$

TABLE OF VISCOSITY STANDARDS

Name of Substance	Mass Density	Viscosity in Centipoises at 25°C
Diethyl ether	0.71	0.22
Ethyl alcohol	0.79	1.20
H_2O	1.00	0.89
Ethylene glycol	1.12	14
Olive oil	0.92	67
Glycerol	1.26	950

The densities for aqueous solutions of sucrose, albumin and other substances are available in the HANDBOOK OF CHEMISTRY AND PHYSICS

APPENDIX J

Operation of Heathkit Oscilloscope

appendix K

The material on this page may be found

TITLE Biology Teacher's Handbook

AUTHOR Joseph J. Schwab

PUBLISHER John Wiley and Sons, Inc. 1968

PAGE NO. 546-548

APPENDIX L

Preparation of Buffer Solutions

pH	ml. 0.2 Molar Na_2HPO_4	ml. 0.1 Molar Citric Acid
2.2	0.20	9.80
2.4	0.62	9.38
2.6	1.09	8.91
2.8	1.58	8.42
3.0	2.05	7.95
3.2	2.47	7.53
3.4	2.85	7.15
3.6	3.22	6.78
3.8	3.55	6.45
4.0	3.85	6.15
4.2	4.14	5.86
4.4	4.41	5.59
4.6	4.67	5.33
4.8	4.93	5.07
5.0	5.15	4.85
5.2	5.36	4.64
5.4	5.58	4.42
5.6	5.80	4.20
5.8	6.05	3.95
6.0	6.31	3.69
6.2	6.61	3.39
6.4	6.92	3.08
6.6	7.27	2.73
6.8	7.72	2.28
7.0	8.24	1.76
7.2	8.69	1.31
7.4	9.08	0.92
7.6	9.37	0.63
7.8	9.57	0.43
8.0	9.72	0.28

APPENDIX M

PROCEDURES FOR OBTAINING TITRATION CURVES

(from an article by Robert Cullen and
Paul Maleskey, William Allen High School
Allentown, Pa.)

TITRATION CURVES:

Data collected using a pH meter can be used to plot titration curves. These curves can be used to illustrate equivalence points, end points, and selection of indicators for manual titrations. Titrations can also be performed using a pH meter in lieu of an indicator.

For the collection of pH data of a sodium hydroxide-hydrochloric acid system titration, you need the following apparatus: pH meter with glass and calomel electrodes; magnetic or overhead stirrer; 50 ml buret (an offset delivery tip is convenient, but not necessary.)

Reagents: 0.10M sodium hydroxide solution (if stoichiometric calculations are desired, this solution should be standardized, using potassium phthalate); 0.10M hydrochloric acid; and buffer solution, pH = 7.00.

PROCEDURE:

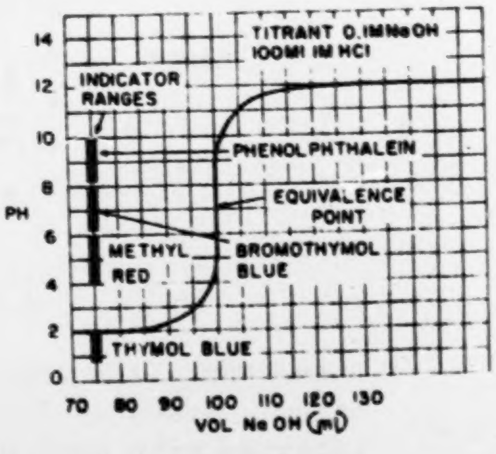
Standardize the pH meter with a small amount of pH = 7.00 buffer solution, according to directions given with the instrument. Using a pipet, transfer exactly 100 ml of 0.10M HCl solution to a 400 ml beaker. Insert the electrodes in the solution so that there is no danger of contact with the stirrer or beaker.

Rinse and fill a 50 ml buret with 0.10M NaOH solution. Adjust the meniscus so that it is at or below the zero mark on the buret. To facilitate calculations, it is convenient to add the titrant in whole number increments. Record and read the buret and pH readings.

Add 10.0 ml increments, wait about 20 seconds for pH to become constant, then read and record the buret and pH readings. At 90 ml, add 1.0 increments. At 98 ml, add 0.5 ml increments, and at 99 ml add 0.1 ml increments. The increments of NaOH to be added may be increased as the titration progresses farther beyond 100 ml. Continue to add NaOH until the pH is approximately 12 and remains relatively constant.

Plot pH on the vertical axis versus volume of NaOH on the horizontal axis, and draw a smooth curve through the experimental points. (See Fig. 1)

Figure 1.



The equivalence point is the point of greatest range of change of pH with addition of a reagent. As shown in Fig. 1, the equivalence point of the NaOH-HCl system will occur at about pH 7. Since the equivalence point corresponds to the inflection point of the graph (the point where the line curvature changes from concave up to concave down, or vice versa), it may be approximated visually.

> NOTE: If stoichiometric relationships are desired, the concentration of the HCl solution may be calculated by equation:
>
> Since $N = \frac{\#\text{eq.}}{\#\text{liters}}$, then
>
> $$N_{acid} \cdot V_{acid} = N_{base} \cdot V_{base}$$

The end point is designated as that point in a titration where an indicator undergoes a visible color change. For stoichiometric use, the end point should coincide with the equivalence point. This relationship can be insured by the proper selection of indicators, as follows:

When the pH range over which an indicator undergoes its color change coincides with a portion of the flat vertical section of the titration curve, it will be a suitable indicator for the titration. To illustrate, the approximate pH ranges of color change of some indicators have been indicated on Fig. 1. Thus it can be seen that phenolphthalein, bromothymol blue, or methyl red would be a suitable indicator. Thymol blue would not be suitable for the NaOH-HCl system.

By conventional methods, a chemical indicator is used in a neutralization titration, and its change of color marks an end point. This should coincide with the equivalence point. Since the latter point can be determined from a titration curve, a titration may be performed (and the corresponding stoichiometric relationships determined) using a pH meter in lieu of an indicator.

DOUBLE INDICATOR TITRATIONS:

Double indicator titrations and selection of indicators can be illustrated with the sodium carbonate-hydrochloric acid system. 1.0 gr of Na_2CO_3 in 100 ml of solution titrated with 0.10 HCl illustrates the two-equivalent point curve.
(See

Figure 2.

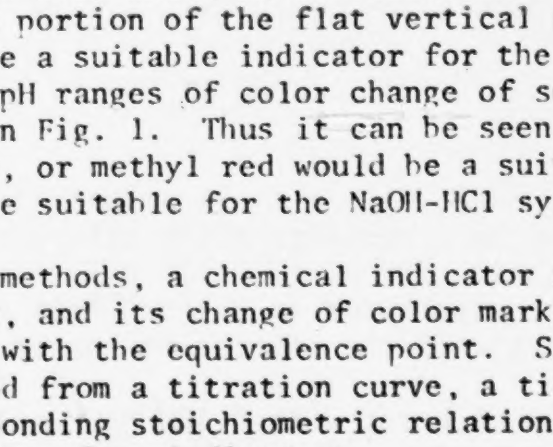
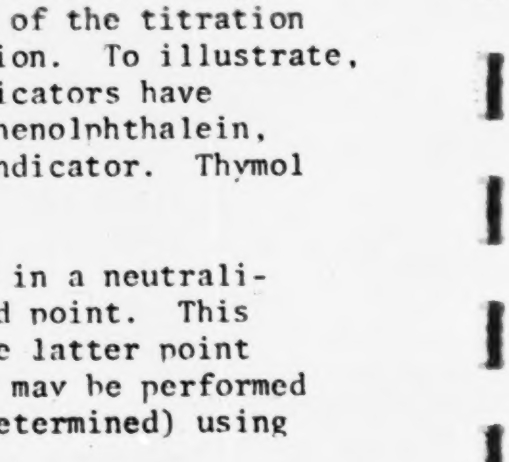


Figure 3.



Phenolphthalein would be a good indicator for the first end point and methyl orange would work well for the second end point. Phosphoric acid titrated with NaOH would also illustrate a polyprotic system (See Fig. 3).

APPENDIX N

TABLE OF CONJUGATE ACID-BASE PAIRS

INCLUDING ACID IONIZATION CONSTANTS

DECREASING ACID STRENGTH

INCREASING BASE STRENGTH

CONJUGATE ACID		CONJUGATE BASE		K_{Acid}
NAME	FORMULA	FORMULA	NAME	
perchloric acid	$HClO_4$	ClO_4^-	perchlorate ion	large (K_A 1)
sulfuric acid	H_2SO_4	HSO_4^-	hydrogen sulfate ion	"
hydrogen chloride	HCl	Cl^-	chloride ion	"
nitric acid	HNO_3	NO_3^-	nitrate ion	"
hydronium ion	H_3O^+	H_2O	water	1
oxalic acid	$HOOCCOOH$	$HOOCCOO^-$	oxalate ion	5.9×10^{-2}
sulfurous acid	H_2SO_3	HSO_3^-	bisulfite ion	1.7×10^{-2}
hydrogen sulfate ion	HSO_4^-	$SO_4^=$	sulfate ion	1.2×10^{-2}
phosphoric acid	H_3PO_4	$H_2PO_4^-$	dihydrogen phosphate ion	7.5×10^{-3}
hydrogen fluoride	HF	F^-	fluoride ion	6.7×10^{-4}
nitrous acid	HNO_2	NO_2^-	nitrous ion	5.1×10^{-4}
acetic acid	CH_3COOH	CH_3COO^-	acetate ion	1.8×10^{-5}
hexaaquoaluminium III ion	$Al(H_2O)_6^{+++}$	$AL(H_2O)_5OH^{++}$	hydroxyopentaaquaaluminium III ion	
carbonic acid	H_2CO_3	HCO_3^-	bicarbonate ion	4.3×10^{-7}
hydrogen sulfide	H_2S	HS^-	hydrosulfide ion	1.0×10^{-7}
dihydrogenphosphate ion	$H_2PO_4^-$	$HPO_4^=$	biphosphate ion	6.3×10^{-8}
bisulfite ion	HSO_3^-	$SO_3^=$	sulfite ion	6.2×10^{-8}
ammonium ion	NH_4^+	NH_3	ammonia	5.7×10^{-10}
hydrogen cyanide	HCN	CN^-	cyanide ion	
bicarbonate ion	HCO_3^-	$CO_3^=$	carbonate ion	5.6×10^{-11}
biphosphate ion	$HPO_4^=$	$PO_4^{\equiv}$	phosphate ion	4.4×10^{-13}
phenol	C_6H_5OH	$C_6H_5O^-$	phenoxide ion	
hydrosulfide ion	HS^-	$S^=$	sulfide ion	1.3×10^{-13}

DECREASING ACID STRENGTH

INCREASING BASE STRENGTH

water	H_2O	OH^-	hydroxide ion	1.0×10^{-14}
ethyl alcohol	C_2H_5OH	$C_2H_5O^-$	ethoxide ion	K_A K_{H_2O}
ammonia	NH_3	NH_2^-	amide ion	"
methylamine	CH_3NH_2	CH_3NH^-	methylamide ion	"
hydrogen	H_2	H^-	hydride ion	"
methane	CH_4	CH_3^-	methide ion	"

HEATS OF COMBUSTION OF SOME
COMMON ORGANIC COMPOUNDS IN CALORIES PER MOLE

Stearic Acid	2,711,000
Sucrose	1,349,000
Glucose	673,000
Ethyl Alcohol	327,000
Lactic Acid	326,000
Acetaldehyde	279,000
Pyruvic Acid	279,000

APPENDIX F

PHYSICAL QUANTITIES AND UNITS

Physical Quantity	Symbol	Definition	F. P. S.	C. G. S.	M. K. S.
Length	d, h l,s,	undefined	foot	centimeter	meter
Mass	m	undefined	slug	gram	kilogram
Time	t	undefined	second	second	second
Temperature	T	undefined	^{o}F	^{o}C	^{o}C
Mag. Pole Strength	m	undefined		unit pole	weber
Electric Charge	q, Q	undefined			coulomb
Area	A	$A= l^2$	foot^2	centimeter^2	meter^2
Volume	V	$V = l^3$	foot^3	centimeter^3	meter^3
Force	F	F = ma	$\frac{\text{slug-ft}}{\text{sec}^2}$ = lb	$\frac{\text{g-cm}}{\text{sec}^2}$ = dyne	$\frac{\text{kg-m}}{\text{sec}^2}$ = newton
Work	W	W = Fd	ft-lb	dyne-cm = erg	newton-meter = joule
Energy	E	E = W stored work	ft-lb	dyne-cm = erg	newton-meter = joule
Power	P	$P = \frac{W}{t}$	550 $\frac{\text{ft-lb}}{\text{sec}}$ = 1 horsepower	$\frac{\text{erg}}{\text{sec}}$	$\frac{\text{joule}}{\text{sec}}$ = watt
Mag. Field Strength.	H	$H = \frac{F}{m}$		Oerstead	weber/meter^2
Velocity	V	V = l/t	foot/sec	cm/sec	meter/sec
Acceleration	a	$a=\frac{V}{t} = \frac{L}{t^2}$	foot/sec^2	cm/sec^2	meter/sec^2
Weight Density	D_w	$D_w= \frac{W}{V}$	lb/ft^3	dyne/cm^3	newton/meter^3
Mass Density	D_m	$D_m = \frac{m}{V}$	slug/ft^3	gram/cm^3	Kg/ meter^3
Pressure	P	$P = \frac{F}{A}$	lb/ft^2	dynes/cm^2	newtons/meter^2
Torque	T	T = Fd	lb-ft	dyne-cm	newton-meter
Impulse	i	i = Ft	lb-sec	dyne-sec	newton-sec
Momentum	p,M	p = mv	slug-ft/ sec	g-cm/sec	kg-m/sec

Physical Quantity	Symbol	Definition	F. P. S.	C. G. S.	M. K. S.
Frequency	f	$f = \frac{no.}{t}$	number/sec	number/sec	number/sec
Potential Difference	V	$V = \frac{W}{q}$			volt
Amperage	I,i	$I = \frac{q}{t}$			ampere
Resistance	R	$R = \frac{V}{I}$			ohms
Electric Field Strength	E	$E = \frac{F}{q}$			volt/meter

APPENDIX R

Length (continued)

1 mile = 1.609×10^{3} meters
1.609 kilometers
1 parsec = 3.0837×10^{16} meters

Magnetism

1 gauss = 1.00×10^{-4} tesla
1.00×10^{-4} weber/meter^{2}
1 maxwell = 1.00×10^{-8} weber (Wb)
1 unit pole = 1.257×10^{-7} weber
1 weber = 1.00×10^{8} maxwell

Mass

1 kilogram = 6.852×10^{-2} slug
1 metric ton = 1.00×10^{3} kilograms
1 slug = 1.4594×10^{1} kilogram
(1 slug weighs 32.17 pounds)
1 unified atomic mass unit = 1.660×10^{-27} kilogram

Mass-Energy

1 joule = 1.113×10^{-27} kilogram
6.705×10^{9} u
1 kilogram = 6.0225×10^{26} u
8.987×10^{16} joules
1 unified atomic mass unit = 1.492×10^{-10} joule

Power

1 horsepower = 550 foot·lbf/second
7.457×10^{2} watts
7.457×10^{-1} kilowatt
1.782×10^{-1} kilocalorie/second
1 kilowatt = 3.413×10^{3} Btu/hour
1.341 horsepower

Power (continued)

1 watt = 1 joule/second
1×10^{7} ergs/second

Pressure

1 atmosphere = 1.01325×10^{5} newtons/meter^{2}
760 mm Hg (0°C)
760 torrs
1 millimeter of mercury (0°C) = 1.333×10^{2} newtons/meter^{2}
1.934×10^{-2} psi (lbf/inch^{2})
1 torr
1 torr = 1 mm Hg (0°C)

Time

1 day (ephemeris) = 1,440 minutes
8.64×10^{4} seconds
1 year = 365.242 days
8.766×10^{3} hours
5.259×10^{5} minutes
3.1536×10^{7} seconds

Volume

1 foot^{3} = 2.8317×10^{-2} meter^{3}
1 gallon (U.S. liquid) = 3.7854 liter
3.7854×10^{-3} meter^{3}
1 liter = 1.00×10^{-3} meter^{3}
1×10^{3} centimeters^{3}
1×10^{3} milliliters
1.0567 quarts (U.S. liquid)
1 quart (U.S. liquid) = 9.463×10^{-1} liter

PHYSICAL CONSTANTS

acceleration due to gravity (standard) g_n	9.80665 m/s^2
alpha particle mass	6.6442 × 10^{-27} kg
atmospheric pressure (normal), atm	1.01325 × 10^5 N/m^2
Avogadro constant, N_A	6.02252 × 10^{23}/mole
Boltzmann constant, k	1.38054 × 10^{-23} J/°K
calorie, thermochemical, cal_{th}	4.1840 J
calorie, International Steam Table, cal_{IT}	4.1868 J
Coulomb law constant, k	2.3063 × 10^{-28} N·m^2/(elem.ch.)^2 8.9876 × 10^9 N·m^2/C^2
electron rest mass, m_e	9.1091 × 10^{-31} kg 5.48597 × 10^{-4} u
elementary charge, e	1.60210 × 10^{-19} C
Faraday constant, F	9.64870 × 10^4 C/equivalent 2.3061 × 10^4 cal/volt/equivalent
gas constant, universal, R	0.082051 atm l/mole/°K 8.314 × 10^7 ergs/mole/°K 8.3143 J/mole/°K 1.987 cal/mole/°K
gas, normal volume, V_o (for perfect gas)	2.24136 × 10^{-2} m^3/mole 2.24136 × 10^1 l/mole
gravitational constant, G	6.670 × 10^{-11} N·m^2/kg^2 6.670 × 10^{-11} m^3/kg·s^2
inch, in	2.54 × 10^{-2} m
liter, l	1.00 × 10^{-3} m^3
molal boiling-point elevation constant for water	0.51°C
molal freezing-point depression constant for water	1.86°C
neutron rest mass, m_n	1.67482 × 10^{-27} kg 1.0086654 u
Planck constant, h	6.6256 × 10^{-34} J·s and 6.6256 x 10^{-27} erg-sec
proton rest mass, m_p	1.67252 × 10^{-27} kg 1.00727663 u
ratio of proton mass to electron mass	1836
Rydberg constant, R_∞	1.0973731 × 10^7/m
speed of light (in vacuum), c	2.997925 × 10^8 m/s
speed of sound (in air at 20°C)	3.44 × 10^2 m/s
unified atomic mass unit, u	1.660 × 10^{-27} kg
water, ice point	273.15°K 0.00°C
water, triple point	273.16°K 0.01°C

PERIODIC CHART

SHELLS

s

d

LIGHT METALS

TRANSITION

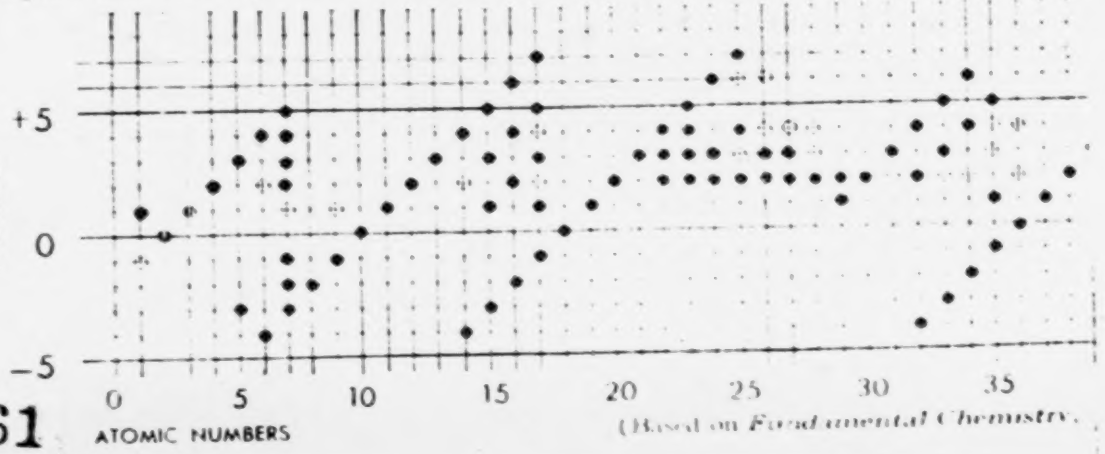
PRINCIPAL QUANTUM No. *n*	X-RAY NOTATION	I A	II A	III B	IV B	V B	VI B	VII B
1	K	1 1 H 1.00797						
2	L	2 1 3 Li 6.939	2 2 4 Be 9.0122					
3	M	2 8 1 11 Na 22.9898	2 8 2 12 Mg 24.312					
4	N	2 8 8 1 19 K 39.102	2 8 8 2 20 Ca 40.08	2 8 9 2 21 Sc 44.956	2 8 10 2 22 Ti 47.90	2 8 11 2 23 V 50.942	2 8 13 1 24 Cr 51.996	2 8 13 2 25 Mn 54.9380
5	O	2 8 18 8 1 37 Rb 85.47	2 8 18 8 2 38 Sr 87.62	2 8 18 9 2 39 Y 88.905	2 8 18 10 2 40 Zr 91.22	2 8 18 12 1 41 Nb 92.906	2 8 18 13 1 42 Mo 95.94	2 8 18 13 2 43 Tc (99)
6	P	2 8 18 18 8 1 55 Cs 132.905	2 8 18 18 8 2 56 Ba 137.34	57-71 See Lanthanide Series	2 8 18 32 10 2 72 Hf 178.49	2 8 18 32 11 2 73 Ta 180.948	2 8 18 32 12 2 74 W 183.85	2 8 18 32 13 2 75 Re 186.2
7	Q	2 8 18 32 18 8 1 87 Fr (223)	2 8 18 32 18 8 2 88 Ra 226	89-100 See Actinide Series				

6	P	LANTHANIDE SERIES (Rare Earth Elements)
7	Q	ACTINIDE SERIES

NOTE: A value given in parentheses denotes the mass number of the isotope of the longest known half-life, or of the best known one.

*The brackets are meant to indicate only the general order of subshell filling. The filling of subshells is not completely regular, as is emphasized by the use of red ink to denote shells which have electron populations different from the preceding element. In the case of He, subshell population is not by itself indicative of chemical behavior, and that element is therefore included in the *inert gas* group, even though helium possesses no p-electrons.

Open circles represent valence states of minor importance, or those



(Based on *Fundamental Chemistry*,

OF THE ELEMENTS

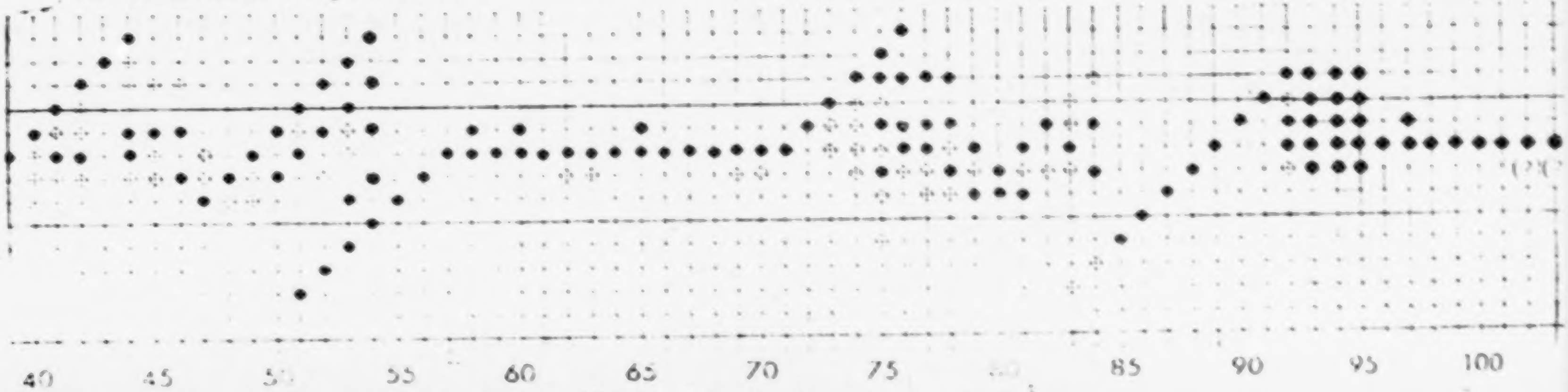
REVISED, 1964

p

HEAVY METALS					NON METALS					INERT GASES
VIII	VIII	VIII	I B	II B	III A	IV A	V A	VI A	VII A	
										2 He 4.0026 2
					5 B 10.811 2 3	6 C 12.01115 2 4	7 N 14.0067 2 5	8 O 15.9994 2 6	9 F 18.9984 2 7	10 Ne 20.183 2 8
					13 Al 26.9815 2 8 3	14 Si 28.086 2 8 4	15 P 30.9738 2 8 5	16 S 32.064 2 8 6	17 Cl 35.453 2 8 7	18 Ar 39.948 2 8 8
26 Fe 55.847 2 8 14 2	27 Co 58.9332 2 8 15 2	28 Ni 58.71 2 8 16 2	29 Cu 63.54 2 8 18 1	30 Zn 65.37 2 8 18 2	31 Ga 69.72 2 8 18 3	32 Ge 72.59 2 8 18 4	33 As 74.9216 2 8 18 5	34 Se 78.96 2 8 18 6	35 Br 79.909 2 8 18 7	36 Kr 83.80 2 8 18 8
44 Ru 101.07 2 8 18 15 1	45 Rh 102.905 2 8 18 16 1	46 Pd 106.4 2 8 18 18	47 Ag 107.870 2 8 18 18 1	48 Cd 112.40 2 8 18 18 2	49 In 114.82 2 8 18 18 3	50 Sn 118.69 2 8 18 18 4	51 Sb 121.75 2 8 18 18 5	52 Te 127.60 2 8 18 18 6	53 I 126.9044 2 8 18 18 7	54 Xe 131.30 2 8 18 18 8
76 Os 190.2 2 8 18 32 14 2	77 Ir 192.2 2 8 18 32 15 2	78 Pt 195.09 2 8 18 32 17 1	79 Au 196.967 2 8 18 32 18 1	80 Hg 200.59 2 8 18 32 18 2	81 Tl 204.37 2 8 18 32 18 3	82 Pb 207.19 2 8 18 32 18 4	83 Bi 208.980 2 8 18 32 18 5	84 Po (210) 2 8 18 32 18 6	85 At (210) 2 8 18 32 18 7	86 Rn (222) 2 8 18 32 18 8

d	f													
57 La 138.91 [illegible]	58 Ce 140.12 [illegible]	59 Pr 140.907 [illegible]	60 Nd 144.24 [illegible]	61 Pm (147) [illegible]	62 Sm 150.35 [illegible]	63 Eu 151.96 [illegible]	64 Gd 157.25 [illegible]	65 Tb 158.924 [illegible]	66 Dy 162.50 [illegible]	67 Ho 164.930 [illegible]	68 Er 167.26 [illegible]	69 Tm 168.934 [illegible]	70 Yb 173.04 [illegible]	71 Lu 174.97 [illegible]
89 Ac (227) [illegible]	90 Th 232.038 [illegible]	91 Pa (231) [illegible]	92 U 238.03 [illegible]	93 Np (237) [illegible]	94 Pu (244) [illegible]	95 Am (243) [illegible]	96 Cm (247) [illegible]	97 Bk (247) [illegible]	98 Cf (251) [illegible]	99 Es (254) [illegible]	100 Fm (253) [illegible]	101 Md (256) [illegible]	102 No (254)	103 Lw (257)

unobtainable in presence of water. For transuranian elements, all valences reported are listed.



nd Edition, [illegible] G. Deming, [illegible] by John Wiley & Sons, Inc.)